VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CXLX.—JUNE, 1881.—VOL. XXIV.

A RATIONAL SYSTEM OF PISTON PACKING.

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Read before the American Society of Mechanical Engineers, May Meeting, Hartford, Conn.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE primary object of a good piston packing is evidently to prevent the working fluid from escaping past the piston. The sole object of the present paper is to investigate how this can be done most efficiently; leaving out of the question all such uses of packing as making it serve the purpose of a carriage for support of the piston, &c.; except, perhaps, a reference to this matter of carriage support—in that it seems desirable to have a carriage for the piston, especially in horizontal engines, and where the cylinder has been bored out larger than the piston to correct irregular wear after some use. But a glance at the matter will show that for the packing to serve as carriage, it must be very wide in order to present the necessary wearing surface for durability, and that where the packing is wide, the rims of the piston must be correspondingly narrow, and be accordingly unfitted for bearing the weight of the piston; and that the flexibility of the packing rings will allow them to take a somewhat irregular form, thus tending to wear the cylinder out of round; and that the devices for setting out the rings may change in intensity of action so as to cause the piston to ride upon the cylinder at some side, causing relatively rapid wear of the narrow rims of piston; and that the piston rod will thus be brought into wearing contact against its packing glands; and that in view of these facts it may be desirable to introduce a groove containing a solid, stout half ring about at the middle of the face of piston to serve as a carriage, with the piston properly jacked upon it: and, finally, that all these devices may be replaced by a considerable breadth of piston rims for support of piston, and narrow packing rings under outward pressure to prevent escape of working fluid. This is all the more evident when we reflect that the piston may be made light—hollow, if necessary, for this end, and the weight added to the cross head or the connecting rod—in which event the piston and cylinder will be subjected to the least possible wear, and thus scarcely need re-boring within the life of the engine. It is evident that this result is preferable to that where the cylinder frequently gets out of form to the extent necessitating repeated re-boring, when the lifetime of the engine will be more or less afflicted with "piston blowing."

Hence, it is proposed, here, to adopt as light a piston as possible, to use very narrow packing rings, and wide rims on the piston, especially for horizontal engines. The simplest possible packing consists of a single ring split upon one side. The simplest piston is one in a single piece, possibly cast hollow for securing desirable form. Hence, a sin-

gle ring, sprung into a groove turned on the face of such a piston, combines the elements of simplicity. Two or more rings may, however, be used on a single piston, each sprung into its own groove.

We will now investigate the single-ring packing. It will appear afterwards that, to set the ring out by pressure of the working fluid transmitted to the underside of the ring through holes, causes excessive frictional contact of the ring upon the surface of cylinder. It would seem desirable, therefore, to give the ring its pressure of contact by means of the inherent stiffness of the ring itself, by turning it larger than the cylinder bore.

A ring, split upon one side and pressing outward with a constant pressure, as it evidently should for greatest efficiency, will necessarily be thicker at points opposite the split, as shown in Fig. 2.

FORM OF PACKING RING.

To find the law of varying thickness, let AB, Fig. 1, represent a piece of such a packing ring, the end or split being at

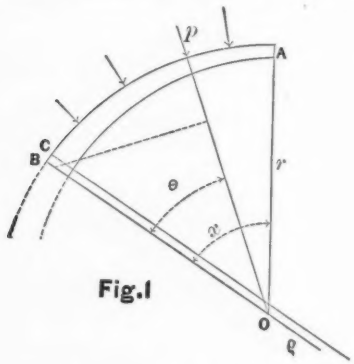


Fig. 1

A. Then the normal pressure of the ring against the cylinder along the outside of AB will be due to a flexural moment, or resistance to bending, of the section of ring at B. This, according to the theory of flexure, will be

$$\text{Flexural moment at B} = \frac{EI}{\rho} \quad . \quad . \quad . \quad (1)$$

where E is the coefficient of elasticity of the material of the ring, I the moment of inertia of the section of ring at B, and ρ the radius of curvature due to the bending. This radius is not to be confounded with the radius of the ring. To define it clearly, draw a line parallel to BO and very near to B as at C. Suppose these lines fixed to the ring, and parallel before flexure. After flexure these lines will intersect at some point more or less remote from B, according to the amount of bending. The distance from B to the point of intersection is ρ. It is evident that if the ring is of circular form before flexure, and also after, ρ will be of constant length for all parts of the ring. As the ring is most conveniently made of circular form, and as it will be used in a circular cylinder, it is desirable that the thickness shall so vary as to realize this and make ρ constant.

According to the theory of flexure, the flexural moment must equal the moment of the applied forces. This latter will, in the present case, be the resultant moment of all the normal pressures on AB. Let P represent the normal pressure per unit of surface of the ring against the cylinder, and if b be the breadth of ring, the pressure per unit of length of ring will be Pb, and for a length $rd\theta$, the pressure will be $Pb.rd\theta$. The moment of this element will be $Pbrd\theta.r \sin\theta$ with reference to an origin of moments at B, where the origin is taken for eq. (1). The integral of this, for θ varied between the limits x and o, will give the total moment of the forces acting on the part AB, or

$$\frac{EI}{\rho} = \int_o^x Pbr^2 \sin\theta \, d\theta = Pbr^2(1-\cos x)$$

$$= 2Pbr^2 \sin^2\frac{x}{2} \quad . \quad . \quad . \quad (2)$$

P being regarded as constant.

Let z be the thickness of the ring at B. Then

$$I = \tfrac{1}{12} bz^3$$

and

$$\frac{EI}{\rho} = \frac{Ez^3}{12\rho} = 2Pr^2 \sin^2\frac{x}{2}.$$

At the middle of ring, or where AB = 180°, we have

$$\frac{Ez_1^3}{12\rho_1} = 2Pr^2$$

whence

$$\frac{z^3}{\rho} = \frac{z_1^3}{\rho_1} \sin^2\frac{x}{2} \quad . \quad . \quad (3)$$

an equation for the whole ring, and giving the relation between z, ρ and x; upon any one of which we may impose arbitrary conditions, the other two remaining mu-

tually variable. If we make z constant, as would follow from turning the ring of uniform thickness, ρ would necessarily vary with x and be infinite at the split when the ring is in use. This would indicate no bending of the ring near the split, and hence the tip end would here bear heavily upon the cylinder, with a probable space of no contact for some distance back. The only useful supposition for x is that it shall remain variable. As pointed out above, considerations of convenience make ρ constant, and hence necessarily equal ρ_1. Hence we have

TABLE OF VALUES FOR LAYING OUT THE RING:

$\frac{x}{2}$	$\sin\frac{x}{2}$	$z=\sin^{\frac{3}{2}}\frac{x}{2}$
5°	.087	.197
10	.174	.311
20	.342	.489
30	.500	.630
40	.643	.745
50	.766	.837
60	.866	.908
70	.940	.960
80	.985	.990
90	.1	.1

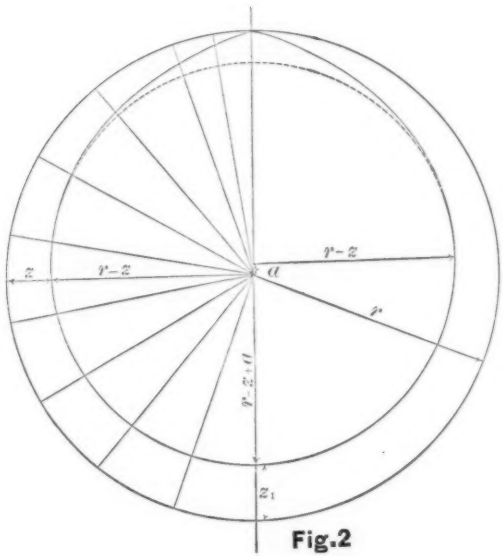


Fig.2

$$z^{\frac{3}{2}}=z_1^{\frac{3}{2}}\sin^2\frac{x}{2} \quad . \quad . \quad . \quad . \quad (4.)$$

for the final equation expressing the law of thickness, z, of ring.

It appears from the equation that the relation between z and z_1 is independent of the radius of the cylinder, and of the pressure of ring against the surface of cylinder. Hence, taking $z_1=1$, a table can be computed for the values of z, by which a ring for any cylinder can be drawn. Then, when the particular value of z_1, for any practical case, is found to be other than 1, the values of z are to be proportionately modified. Making $z_1=1$, we find the following

By these values the ring is drawn in Fig. 2 to a scale. The outside is taken, the circle of the cylinder into which the ring is supposed to be compressed when ready for service.

From this drawing it is found by placing one leg of a pair of dividers a distance, a, toward the split of the ring, and swinging the other leg about near the inside edge of ring, that about $\frac{2}{3}$ of the inner line of ring lies almost exactly on the arc of a circle, and with its center at a certain distance, a, from the center of the exterior of ring. The distance of this center from the inner surface of ring opposite split is $r-z_1+a$, the radius of the inside circle of ring.

At the intermediate point of 90° from the split, this center is at a distance

$$r-z=r-z_1 \sin^{\frac{3}{5}} 45°$$

from the inner surface of ring, which is also the radius of the inside circle. Making these distances equal, we find

$$r-z_1+a=r-z_1 \sin^{\frac{3}{5}} 45°$$
$$a=z_1(1-\sin^{\frac{3}{5}} 45°)$$
$$a=0.206\, z_1 \text{ nearly} \quad . \quad . \quad (5)$$

If it be assumed that this circle gives the inner form of the ring with a sufficient degree of exactness, for about $\frac{2}{3}$ its extent, the ring can be formed in a turning lathe complete, except for the $\frac{1}{3}$ of inside surface, a half which is on each side of split. This could be dressed off subsequently. The lathe work would then most conveniently consist of mounting upon a face plate, or in a chuck, acylindric shell long enough to make several rings, with a stay of cross arms. The inside is to be first bored deep enough for several rings, and then the ring offset to the eccentricity $a=.206\, z_1$, and the outside turned off. The rings are then to be cut off with such breadth as desiried. The eccentricity is observed to be a little over $\frac{1}{5}$ the greatest thickness of ring.

In practice the tip ends of the ring at the split should be lapped a little, instead of being as shown in Fig. 2. A suitable way of doing this is shown in Fig. 3. For a perfect and complete stop

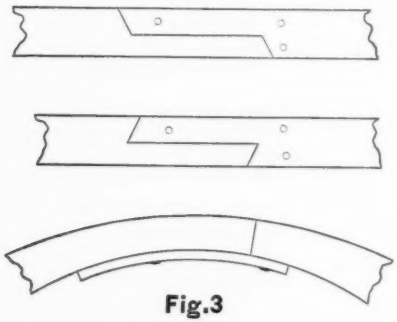


Fig.3

to the working fluid by ring, a strip should be riveted upon the under side of one tip so as to lie close to the under side of the other tip when in place, as shown. Otherwise, when the ring has worn so as to separate a little at the tips, the working fluid may enter between the tips at one side, pass under the ring to the opposite side, thence out and escape. It is evident that for thus lapping the tips, the thickness, to that extent, should be constant, and not vary as in Fig. 2. To adjust the bearing of the lapping part against the cylinder, it is plainly necessary to dress off a trifle of the over-lapping tip outside, to compensate for the increased stiffness due to the deviation from Fig. 2, to a uniformity of thickness. The extent to which the tips may be made to overlap, as in Fig. 3, for a given excess of diameter at which the ring may be turned, will be considered subsequently.

OUTWARD PRESSURE OF RING.

It is evident that the outward pressure of the ring against the inside surface of cylinder will depend upon the diameter of the ring, its thickness, and the excess in diameter being given it when turned.

Let A be the center of the ring when turned to the radius r_1, and B the center when it is compressed into the cylinder of radius r_1. Let DC be a small part of that ring, so that

$$DC=rd\theta=r_1 d\theta'=\rho\, d\theta'' \quad . \quad . \quad . \quad (6)$$

ρ being the radius of curvature due to the bending or compressing of the ring,

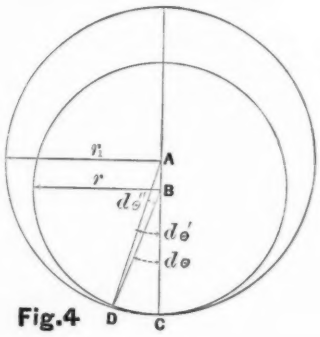


Fig.4

to change it from r_1 to r, Fig. 4, makes it evident that

$$d\theta''=d\theta-d\theta' \quad . \quad . \quad . \quad . \quad (7)$$

By aid of (6) and (7) we may write

$$\frac{d\theta-d\theta'}{d\theta}=\frac{r_1-r}{r_1}=\frac{d\theta''}{d\theta}=\frac{r}{\rho}$$

whence $$\frac{r}{\rho}=\frac{r_1-r}{r_1} \quad . \quad . \quad . \quad . \quad (8)$$

But as a constant value of ρ has been adopted, $\rho=\rho_1$, and hence, combining (8) with the equation preceding (3), we have

$$\frac{Ez_1^3}{12}\cdot\frac{r_1-r}{r_1 r}=2Pr^2$$

whence the amount of normal pressure of ring per square unit is

$$P=\frac{E}{24}\cdot\frac{z_1^3}{r^3}\cdot\frac{r_1-r}{r_1}.$$

Hence, it appears that the intensity of pressure of ring upon cylinder will vary directly as the cube of the thickness, and nearly as the excess of diameter at which the ring is turned.

This excess in external diameter, of ring over the cylinder bore, is arbitrary. But in assuming the excess, probably no one would take the mean diameter of ring, inside and outside, less than that of the cylinder bore. A little consideration would probably fix it larger. If we adopt such a relation that $\frac{2}{3}$ of the ring will be outside the groove when first sprung into it, we have

rad. of piston, $r=r_1-\frac{2}{3}(r_1-\text{inside rad.})$.

But inside rad. $=r_1-z_1+a=r_1-.794\,z_1$

$$\therefore\ r=r_1-.529\,z_1$$

$$\therefore\quad \frac{r_1-r}{r_1}=\frac{.529\,z_1}{r_1}=.5\,\frac{z_1}{r}\text{ nearly.}$$

Hence $$P=\frac{E}{48}\,\frac{z_1^4}{r^4} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

TENDENCY OF FLUID TO LIFT THE RING.

In a thin space between the ring and cylinder, the fluid will flow, as shown in Fig. 5, from p_1 to p_2, the frictional resistance of an inelastic fluid like water in the space t, hindering the flow, and giving cause, for pressure upon ring; and in elastic fluids, like air, both the frictional resistance and expansive pressure in the space, t, between ring and cylinder, will have a combined effect to press the ring back, and to increase the space for escape.

1. *Case of Ordinary Water Pump.*—Here the density does not sensibly change between p_1 and p_2. In this case

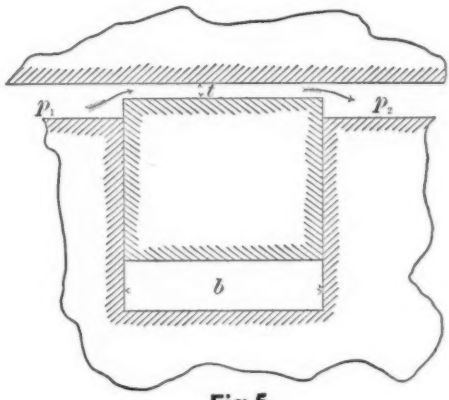


Fig.5

the velocity of flow will be constant within the space t, and the reduction of pressure will be in two parts; first, for acceleration at entry to the space, and second, for frictional resistance along the space. According to an article which I have lately published in VAN NOSTRAND'S ENGINEERING MAGAZINE (see p. 372),

$$h'+h''=h=\frac{v^2}{2gu^2}+\frac{fsl}{a}\frac{v^2}{2g}=\frac{p_1-p}{d}+\frac{p-p_2}{d},$$

or $$p_1-p=\frac{\delta v^2}{2gu^2} \quad . \quad . \quad . \quad . \quad (10)$$

for entry, and

$$p-p_2=\frac{\delta fsl}{a}\,\frac{v^2}{2g} \quad . \quad . \quad . \quad (11)$$

for the space t, in which v is the velocity in the space, u the coefficient of velocity for the orifice of entry, here about 0.85;

δ the weight per unit of volume of the flowing fluid; a, the sectional area, transverse to the flow, of so much of the space t as is considered; s, the perimeter of the same section; f, the coefficient of friction of the fluid against the ring or cylinder; $l=b$, the length in the direction of motion of the flowing sheet, or breadth of ring; and p, the absolute pressure of fluid just within the entrance to the space t. The pressure will gradually decrease, from p to p_2, as the fluid passes along the space t. If x be taken for the distance from the p_2 side of ring, we have

$$p-p_2=\frac{\delta fsx}{a}\frac{v^2}{2g} \quad . \quad . \quad . \quad (12)$$

where p will now be the pressure of fluid in the space t at the distance x. This pressure tends to push the ring back, and it being variable, the total amount of it for the whole breadth, b, of ring and for a unit's length along the ring, will be,

$$\mathrm{P}b=\int_0^b p\,dx=\int_0^b\left(\frac{\delta fs}{a}\frac{v^2}{2g}x+p_2\right)dx \quad . \quad (13)$$

$$=\frac{\delta fs}{a}\frac{v^2}{2g}\frac{b^2}{2}+p_2b=(p-p_2)\frac{b}{2}+p_2b$$

by eq. (11). Hence

$$\frac{\mathrm{P}}{p_2}=\tfrac{1}{2}\left(1+\frac{p}{p_2}\right) \quad . \quad . \quad (14)$$

and numerically for

$\frac{p}{p_2}=2$	$\frac{\mathrm{P}}{p_2}=1.5$
4	2.5
6	3.5
8	4.5
10	5.5

(A)

an expression giving in terms of the pressures of fluid at opposite edges of packing ring, the ratio of the total pressure tending to push the ring away from the cylinder to the pressure at the exhaust side of piston. These pressures are per square unit of area absolute. A noticable fact is that this ratio is independent of the breadth of ring, of the density of fluid, and of the coefficient of friction, except so far as p may depend upon them. That p will not coincide with p_1 is evident from (10).

To find the relative proportions of fall of pressure due to (10) and (11), we may take their ratio. Hence

$$\frac{p_1-p}{p-p_2}=\frac{a}{fsbu^2}=\frac{t}{2fbu^2} \quad . \quad . \quad . \quad (15)$$

in which $$\frac{a}{s}=\frac{t}{2}$$

since for a given extent, k, along the ring

$$a=kt \quad s=2k.$$

Hence, the fall of pressure varies only with t and b, the thickness of space and length of flow between ring and cylinder. But it will, of course, be desirable that t be very small, far within the hundredth part of an inch. If, for example, it be taken in thousandths of an inch, we have for $f=.006$, $b=.5$ and $u^2=.7$

$t=1$ thousandth	$\frac{p_1-p}{p-p_2}=$	.238
2 "		.476
4 "		.952
8 "		1.904
1 hundredth		2.381

(B)

Hence, with a thickness of space t, of a little over 4 thousandths of an inch, half the fall of pressure from p_1 to p_2 will be consumed in entering the fluid into the space t. As the thickness of this space thus appears to be an important element in determining $\frac{\mathrm{P}}{p_2}$ and consequently the thickness z_1 of ring, the latter diminishing with P, it becomes desirable to determine the admissible limits of t. This is to be done by aid of the equation just preceding (10), whence the velocity of escape is found by

$$v^2=\frac{p_1-p_2}{\delta}\cdot\frac{2g}{\frac{1}{u^2}+\frac{2fb}{t}} \quad . \quad . \quad . \quad (16)$$

The percentage of the whole piston displacement in the volume escaping past the piston will be

$$\frac{q}{\mathrm{Q}}=\frac{v\times\text{area of whole space }t}{\text{piston displacement}}=\frac{v\times 2\pi rt}{\pi r^2\mathrm{V}}$$

$$=\frac{2vt}{r\mathrm{V}}$$

where V is the piston speed in ft. per sec.

Combining this with (16) by eliminating v, and we obtain,

$$\left(\frac{q}{Q}\right)^2=\frac{\frac{8gt^2}{r^2V^2\delta}\left(\frac{p_1}{p_2}-1\right)}{\frac{1}{u^2}+\frac{2fb}{t}} \quad . \quad (17)$$

If it is desired to take account of the effect of the motion of piston and of packing ring, upon the actual velocity of fluid escape, we find the latter to be,

$$v-\frac{V}{2}$$

and then the first member of (17) should be

$$\left(\frac{q}{Q}+\frac{t}{r}\right)^2$$

This may be put in a more convenient form by factoring and tabulating a part. Thus, if $d=2r=$ diam. of piston,

$$\frac{q}{Q}+\frac{2t}{d}=\frac{1}{Vd}\sqrt{\frac{p_1}{p_2}-1}\,(\text{Tab. val.}) \quad (18)$$

where, for water pump rings, of a width $b=.5$ of an inch, and for $t=1, 2, 5, 10$, thousandths of an inch.

Tab. val. = .0057 .014 .0480 .1092 (C.)

For these values p_2 is taken at one atmosphere.

To obtain an idea of the practical values of (18), we have, for a piston speed of pump piston of $V=2$ *ft* per sec.,

$d=\frac{1}{2}$ ft., or $Vd=1$, and $\frac{p_1}{p_2}$ in atmospheres.

For t in inches. =	1	2	5	10	[thousandths
$\frac{p_1}{p_2}=2,\ldots.\frac{q}{Q}=$	.005	.010	.048	.109	(D)
" $=8,\ldots.$ " $=$	.015	.027	.127	.288	

the term $\frac{2t}{d}$ being inconsiderable.

As the maximum admissible leakage of piston would probably be assumed from 1 to 5 per cent. of piston displacement, it appears that the greatest admissible thickness of space, t, is about 2 thousandths of an inch in pumps.

This thickness, compared with the table of values for eq. (15) indicates that we may count on

$$\frac{p_1-p}{p-p_2}=\text{not greater than } o \text{ to } .5.$$

or the fall of pressure on entering the space t, should not exceed a half of the fall due to passing the ring; or, it should not exceed a third of the total fall from p_1 to p_2. In other words, the fall of pressure, $p-p_2$, in passing the ring, should not be less than two-thirds of the total difference p_1-p_2 of pressure on opposite sides of piston.

To illustrate further, let the pump be working where

$\frac{p_1}{p_2}=6$ and $\frac{2}{3}$ of this, gives $\frac{p}{p_2}=4$.

Then the table for eq. (14) gives

$$\frac{P}{p_2}=2.5 \text{ for } \frac{p}{p_2}=4;$$

and this, combined with eq. (9), gives

$$2.5\,p_2=\frac{Ez_1^4}{48r^4}.$$

If $p_2=1$ atmosphere $=15$ lbs. per sq. inch, and if the ring be made of cast iron, as probably a good material, when $E=20{,}000{,}000$. Then

$$\frac{z_1}{r}=.097.$$

If the pump has a 12″ cylinder

$$z_1=.584 \text{ inch}$$

so that for the conditions assumed, a 12-inch piston packing ring for a pump will be about $\frac{2}{3}$ of an inch thick at the thickest place.

The eccentricity, a, for use in turning the ring will be

$a=.206\,z_1=.12$ inch, or about $\frac{1}{8}$ of an inch.

These results are for a pump where the pressure p_2, on the suction side of piston, is one atmosphere; and p_1, on the pressure side, six atmospheres.

For similar conditions, except the working pressure $p_1=2$ atmospheres, we have

$z_1=.496$ inch, or about half an inch.

$a=\frac{1}{10}$ inch.

It is noticeable, from eq. (9), that z_1 is proportional to r for a given pressure, so that the thickness of ring for other sizes than 12″ pistons, can readily be obtained.

If we ignore the refinements about the orifice of entry, and assume p as identical with p_1, we only require formulas (14) and (9) to determine the ring. In fact, they may be combined, giving

$$\left(\frac{z_1}{r}\right)^4=\frac{24p_2}{E}\left(1+\frac{p_1}{p_2}\right) \quad . \quad . \quad . \quad (19)$$

Values of z_1 computed by this for the

above examples give .636 and .515 respectively, in place of .584 and .496 as corrected for the orifice of entry.

These differences being comparatively unimportant, the effect of orifice of entry will be ignored in the following cases:

2d. *Case of an Elastic Fluid like Air.*—Here the flow will be at some intermediate condition between the adiabatic and isothermal for the gas while escaping the packing ring. Considering it adiabatic, the proper expression taken from the article previously referred to, is:

$$\frac{f}{a}\frac{s}{2g}\frac{v_2^2}{}\,b=\frac{\gamma}{\gamma+1}\,\frac{p_2}{\delta_2}\left\{\left(\frac{p_1}{p_2}\right)^{\frac{\gamma+1}{\gamma}}-1\right\}$$

where v_2 is the velocity of escape and p_2, and $\gamma=1.408$ for a perfect gas. For the present case this eq. may be put under the following form:

$$\mathrm{A}b=\left(\frac{p_1}{p_2}\right)^{\frac{\gamma+1}{\gamma}}-1 \quad . \quad . \quad . \quad (20)$$

or for shorter distances, x, reckoned from the exit side of ring where also the pressure will be p, we have

$$\mathrm{A}x=\left(\frac{p}{p_2}\right)^{\frac{\gamma+1}{\gamma}}-1$$

or

$$(1+\mathrm{A}x)^{\frac{\gamma}{\gamma+1}}=\frac{p}{p_2}$$

The value of p from this, introduced into eq. (13) and integrated, gives

$$\mathrm{P}b=\frac{p_2}{\mathrm{A}}\,\frac{\gamma+1}{2\gamma+1}\left((1+\mathrm{A}b)^{\frac{2\gamma+1}{\gamma+1}}-1\right).$$

Restoring the value of A by aid of (20) we obtain

$$\frac{\mathrm{P}}{p_2}=\frac{\gamma+1}{2\gamma+1}\left\{\frac{\left(\frac{p_1}{p_2}\right)^{\frac{2\gamma+1}{\gamma}}-1}{\left(\frac{p_1}{p_2}\right)^{\frac{\gamma+1}{\gamma}}-1}\right\} \quad . \quad . \quad . \quad (21)$$

an expression in terms of p_1 and p_2 only. Hence a table is readily computed for practical use, thus:

If $\frac{p_1}{p_2}=4$	$\frac{\mathrm{P}}{p_2}=2.72$	
6	3.94	(E)
8	5.18	
10	6.42	

By employing these values of P in (9), the thickness of ring, z_1, can be calculated.

If the flow past the ring be regarded as isothermal, γ, in equation (21) is to be taken equal 1, and hence

$$\frac{\mathrm{P}}{p_2}=\frac{2}{3}\left\{\frac{\left(\frac{p_1}{p_2}\right)^3-1}{\left(\frac{p_1}{p_2}\right)^2-1}\right\} \quad . \quad . \quad . \quad (22)$$

and hence the following table:

If $\frac{p_1}{p_2}=4$	$\frac{\mathrm{P}}{p_2}=2.80$	
6	4.09	(F)
8	5.41	
10	6.73	

These values of P differ only slightly from those in (E), so that as regards the pack-ring question, since the 4th root of these quantities is to be taken in (9), the difference for the adiabatic and isothermal condition is entirely insignificant. Even compared with the table (A) for pump-packing rings, the 4th root will differ but slightly for a given ratio of pressures p_1 and p_2.

Hence, the following table will be found to cover nearly the whole range of practice:

PRACTICAL TABLE FOR SINGLE RING PACKING.

		Pumps.	Engines, &c.
For $\frac{p_1}{p_2}=4$	$\frac{z_1}{r.p_2^{\frac{1}{4}}}=$	.0495	.0509
6		.0538	.0560
8		.0573	.0600
10		.0603	.0634

p_1 = higher absolute pressure, lbs. per square inch, on piston.
p_2 = lower absolute pressure, lbs. per square inch, on piston.
r = radius of cylinder bore, in inches.
z_1 = thickest place in the packing ring, in inches.
Eccentricity of a ring $=a=z_1$ .206.

The ring is supposed to be turned so that when sprung into its groove, $\frac{2}{3}$ of it will lie outside of the groove before the piston is put into the cylinder. This is realized by making the outside diameter of ring when turned =

$$d_1=d+z_1 \text{ nearly}$$

where d= the diameter of cylinder bore

The inside diameter, d_2, at which to bore out the ring will be $2(r-z+a)$, or

$$d_2 = d_1 - 1.588\, z_1$$
$$= d_1 - 1.6\, z_1 \text{ nearly.}$$

The groove for the ring is to be turned out on the solid face of the piston, the depth being somewhat greater than the thickest place z_1 of ring.

The width of the groove should be such as to give an accurate free fit to the ring.

The width of ring is arbitrary, the above formulas (9), (14), (21) and (22) for determining the ring, not containing any term for breadth. The total pressure of ring against the cylinder is proportional to the width for a given thickness. Hence, the pressure per square inch of surface is constant. The rate of wear of the ring from its surface will be proportional to the pressure per square inch. Hence, a wide ring will wear no longer than a narrow one. A wide ring will, however, wear the cylinder bore more than a narrow one, and also leave narrower rims on the piston for wear. Hence, as a narrow ring is, according to the formulas, as efficient in preventing the escape of the working fluid as a wide one, it is decidedly best to adopt a narrow ring, usually not to exceed a half an inch.

In forming the lap shown in Fig. 3, a portion of the ring must be cut away. The demand for this is met in the ring being turned larger than the cylinder, thus requiring some to be cut from it.

According to directions above, the excess in diameter over the cylinder bore, at which the ring is turned is z. If the ring did not elongate along its exterior surface as it is sprung into the cylinder, we would find the amount to cut out $= \pi z_1$, since the outside lengths of the ring, before and after, would be $\pi d_1 = \pi (d + z_1)$ and πd, the difference of which is πz_1. But as the outside elongates slightly in the flexure, we find by considering the amount of flexure, position of the neutral axis, &c., that the amount to cut from the ring $= \pi z_1 \left(1 + .397 \frac{z_1}{r}\right)$

In regard to setting the ring out by pressure of working fluid beneath it, introduced through holes from the pressure side of piston, it is evident that the pressure of ring upon cylinder per square inch will be nearly p_1, while the above figures make it P. The former pressure, as seen by tables (A), (E) and (F), is about 50 per cent. greater than the latter, showing that the so-called steam packing is to that extent too heavily set,

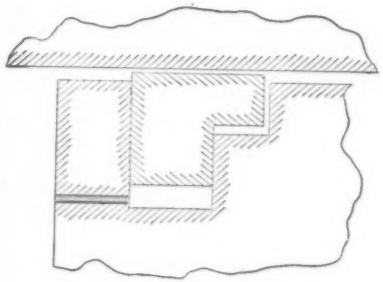


Fig.6

causing undue wear, resistance, &c. The steam-packing ring should, therefore, be made as in Fig. 6, with pressure under only a part of it, the wing being relieved to prevent receiving pressure.

When several rings are employed on one piston each might be so designed as to act for reducing only part of the pressure, and the rings could be made somewhat thinner than where one is depended upon for making the joint. The "practical table," however, indicates only a reduction in thickness of from a fourth to a third.

THE construction of the St. Gothard Railway, on the Tunis side, is now, the Geneva correspondent of the *Times* says, in so forward a state that the completion of the section between Airolo and Bellinzona by the end of June is regarded as certain. The section between Bellinzona and Locarno has been in running order for some time. Owing, however, to the condition of the great tunnel, where the so-called windy stretch, a bed of rotten limestone and gypsum, which swells on exposure to the air, is still breaking the engineers' hearts, the line is not likely to be ready for through traffic before October, if then. The Federal tribunal have decided against the contractors for the great tunnel in respect of their demand for a prolongation by 780 days of the time fixed for the completion of the work.

THE METRIC SYSTEM.

From the Proceedings of the Boston Society of Civil Engineers.

THE Committee* on the Metric System of Weights and Measures presents this report in obedience to the vote passed at the last annual meeting, March 17, 1880, that "The Committee on the Metric System shall gather, from time to time, and present to the Society, all attainable information relative to the progress toward the introduction of the metric system into this country and the world at large."

FOREIGN COUNTRIES.

As for the world at large, its chief nations, as they have emerged from the barbarous state of warring tribes, have passed laws (as the United States has done) to make weights and measures uniform throughout each nation's domain. Now that international communication has been so enormously developed—that it is easier than was communication between different parts of the same nation at the beginning of this century, there is exactly the same occasion for laws establishing international uniformity. Among foreign nations the progress in this direction during the past year has consisted chiefly in the execution of laws previously enacted for the adoption of the metric system.

In Sweden, for instance, the beginning of 1881 is the time that was fixed for its use to become obligatory, for customs and postal purposes, and for railroad transportation as was stated in the report of the chief clerk of the United States Treasury Department, dated March 26, 1878.

In Switzerland, the latest information contained in that report showed that the use of the pure metric system was optional, side by side with an old compromise system; it has now been made obligatory. The attention of some patriots in the United States is invited to the fact that this change was accomplished without bloodshed, and that Switzerland still maintains a republican form of government.

In German handbooks of mechanics, Mr. Coleman Sellers states that formulas used to be expressed both in meters and in Prussian inches, but that with the year 1880 the inch was dropped whereever possible.

From Greece, a merchant of this city has recently imported wine in liters, whereas a few years ago it came in old measures.

More important to us is the following, quoted from the "Railroad Gazette" of July 9, 1880: "The metric system, on the 15th of July, becomes obligatory in the kingdom of Spain and all its colonies, including Cuba, with which our commercial relations are very intimate. The Turkish government has also ordered the introduction of this system into all its provinces, including Tripolis and Arabia. The cubit gives way to the meter in Jerusalem, and the shekel to the kilogram."

The significance of this lies in the fact that from Cuba, Porto Rico, and other Spanish possessions come about one-sixth part of our imports. Before this change our imports from Great Britain and her colonies were of nearly the same value as our imports from all countries where the metric system is established; the addition to the latter class of our imports from the Spanish colonies will make that class include about fifty per cent. more than the value we import from Great Britain and the British possessions, and will make it amount to more than than half the total imports through the custom houses of the United States.

NOTE.—The following table of our imports from foreign countries, grouped according to their metric legislation, for the year ending June 30, 1877, is taken from the report already mentioned of the chief clerk of the Treasury Department, with the single change of the Spanish possessions from the class of countries where the metric system is legalized to that where its use is obligatory. Austria, Turkey, Sweden and

*The Committee was composed of Fred. Brooks, L. Frederick Rice, and Clarence W. Lunt.

Norway are left just where he placed them about three years ago:

METRIC SYSTEM OBLIGATORY.

Argentine Republic	$3,449,559
Belgium	5,079,149
Brazil	43,498,041
Chili	698,716
France and French possessions	52,862,387
Germany	33,035,485
Greece	523,128
Italy	7,105,366
Mexico	15,444 583
Netherlands	2,547,119
Peru	1,545,461
Portugal	524,828
Roumania	—
San Domingo	560,709
Spain	3,280,836
Spanish possessions (Cuba, Porto Rico, etc.)	79,544,185
Switzerland	—
United States of Columbia	5,454,393
Uruguay	2,197,711
	$257,351,654

METRIC SYSTEM LEGALIZED.

Great Britain and British possessions	$185,667,400

METRIC SYSTEM PARTIALLY IN USE.

Austria	$414,020
Azores, Madeira, and Cape de Verde Islands	92,351
Central American States	2,883,602
Denmark	9,053
Japan	13,689,433
Sweden and Norway	243,562
Turkey in Europe	46,714
	$17,378,735

METRIC SYSTEM NOT LEGALIZED OR IN USE.

Danish West Indies	284,480
Dutch East Indies	4,511,444
Dutch West Indies and Dutch Guiana	735,525
China	11,141,447
Greenland	137,465
Hawaiian Islands	2,631,763
Hayti	3,303,709
Liberia	57,470
Russia	618,534
Turkey in Asia and Africa	382,303
	$23,804,140

SUMMARY.

Imports from countries where the metric system is	Obligatory	$257,351,654
	Legalized	185,667,400
	Partially in use	17,378,735
	Not legalized or in use	23,804,140
	Total	$484,201,929

In regard to the British item above, it should be observed that the British colonies do not all use the imperial weights and measures. Mauritius adopted the metric system a few years ago; in India its ultimate adoption is provided for by the Indian Weights and Measures Act, 1870, but various native units are now chiefly used. On the other hand, in some of the countries where the metric system has been made obligatory by law, its introduction has not yet been completely effected.

Another and more important observation is that the British capacity measures are incommensurable with those of the United States.

It might be added, paradoxically, that the United States standard of weight is very different from that of Great Britain, for in Prof. Hilgard's report on American Standards of Length, dated July 10, 1880 (being Appendix No. 12 to the Coast and Geodetic Survey Report for 1877), it is stated that "no enactment by Congress has ever been made, declaring particular measures in the keeping of the government as standards, except the standard troy pound of the Mint of the United States, at Philadelphia, procured in 1827," etc., but the troy pound has been abolished in Great Britain, as may be seen from the compulsory Weights and Measures Act, 1878, of the British Parliament. A point of real importance is that the British ton is fixed at 2,240 pounds, while the ton of the United States is a varying quantity and may be represented by x.

As there is some nonsense afloat about what is miscalled the "Anglo-Saxon" race, your committee remarks that the people of England gracefully submit to these "arbitrary" enactments made by their own chosen representatives in Parliament assembled.

UNITED STATES CUSTOM HOUSES.

As to legislation, the progress toward the introduction of the metric system into the United States may be gauged by the fate of the bill, H. R., No. 411, introduced in the present Congress, April 21, 1879. It provides that the *ad quantum* duties upon articles imported with metric invoices shall be assessed at metric rates, which, by throwing off awkward fractions, are made to favor very slightly the use of the metric system in invoices.

A year ago the American Metrological Society was circulating a memorial in fa-

vor of such legislation. The memorial was printed in "Engineering News" of March 20, 1880. It was signed by fifty gentlemen out of eighty-eight, whose names are on the printed list of active members of the Boston Society of Civil Engineers, dated January, 1880. It was offered to twenty others, who did not sign it; and your committee does not know of its being presented at all to the remaining eighteen. This is believed to be the best test hitherto obtained (though an imperfect one) of the opinions of the individual members of this Society. The memorial was also signed by about six thousand other persons. A memorial against any further legislation to facilitate the introduction of the metric system has been circulated (but not in the Boston Society of Civil Engineers) by the International Institute for Preserving and Perfecting Weights and Measures. It was printed in "Engineering News" of April 10, 1880. From the same source another memorial to eradicate the metric system from the Coast and Geodetic Survey and other government offices is in preparation.

The following card, dated at Cleveland, April 12, 1880, was issued by Charles Latimer, the chief engineer of the New York, Pennsylvania and Ohio Railroad:

"As the active executive officer of the International Institute for Preserving and Perfecting Weights and Measures, I wish to warn the public, and especially mechanics and other workingmen, against the attempts now making to introduce the French metric system into this country by a compulsory Act of Congress. This is being done under false pretences, by wording their petitions for the people to sign, so as to convey the idea that they are asking for a decimal system of weights and measures in accord with our decimal system of money, when the measure they are trying to secure is the French metric system, pure and simple, with all its barbarous Greek and Latin names unknown to our people and illy adapted to our language. To accomplish this purpose, petitions to Congress, asking simply for a decimal system of weights and measures, as above stated, are being circulated, while the country is being flooded with books, pamphlets, and other publications on the subject, worded in the most specious and attractive style, so as to draw the most money from the unwary. The purchase of such documents is only a waste of money, tending to evil instead of good, making the rich richer and the poor poorer. Besides, many well-informed persons are strong in the belief that this whole movement is a deliberate attempt to subvert our republican government, to bring our people into a condition where such arbitrary measures can be forced upon them at the point of the bayonet, if need be."

In the Civil Engineers' Club of the Northwest, which has now been reorganized as the Western Society of Engineers, the following resolution, moved by Mr. Greeley, was adopted May 4, 1880, by a vote of sixteen to thirteen; six of the sixteen affirmative votes and eight of the thirteen negative votes were cast by letter ballot or proxy.

"*Resolved*, That in the opinion of this Club the substitution at some future time, to be hereafter determined, of the metric system of weights and measures for those now in use in the United States, is to be desired; and that as a step towards this change, we favor the recommendation made at the last session of the Forty-fifth Congress, and renewed at the special session of the Forty-sixth Congress, by the Committee on Coinage, Weights and Measures, of the House of Representatives, that an act should be passed requiring the use of the metric denominations of weight and measure in the custom houses of the United States."

During the first annual meeting of the American Society of Mechanical Engineers, Nov. 5, 1880, the following resolutions were offered by Mr. Henry R. Worthington (who has since died):

"*Resolved*, That this society deprecates any legislation tending to make the adoption of the metric system of measures obligatory in our industrial establishments;" also,

"*Resolved*, That the secretary be instructed to communicate the sentiments of this resolution to all concerned in procuring such legislation, and also to send a copy to the Anti-Metric Society of Cleveland."

A letter ballot was ordered to be taken upon these resolutions. Your commit-

tee has not yet been honored with any copy from the secretary, as proposed, but presumes that sooner or later a ballot will be taken. Whatever be the result of this ballot, as a custom house is not considered an "industrial establishment," the world will remain in doubt as to what the Mechanical Engineers think about the government's using the metric system in the transaction of its own business of collecting specific duties upon such imports as are invoiced in meters and kilos.

A pertinent quotation, though several years earlier in date, may be made from the report of a special committee of the American Society of Civil Engineers relative to the memorials which the American Metrological Society addressed to a former Congress in behalf of the metric sytem. The report was signed by R. H. Thurston and J. J. R. Croes; it was presented to the American Society of Civil Engineers, May 6, 1874, and was laid on the table; the quotation is: "A series of legal enactments, carefully considered, cautiously introduced, and steadily pursued, is considered the proper, the wisest, and the necessary course to be pursued in the endeavor to attain these great benefits."

Bill H. R., No. 411, is still pending in the Forty-sixth Congress. The Committee on Coinage, Weights and Measures had printed, during the second session, Report No. 203, relating to coinage, and Mis. Doc. No. 29, containing Col. Thomas S. Sedgwick's scheme for decimalizing the foot and ounce, and abandoning the present inch, pound, and other units, together with a reply from Dr. Culver, the clerk of the committee, in advocacy of the metric system.

PROFESSIONAL USE.

In advance of any legislation to give people a definite idea at what time the change of standard is likely to be effected, the metric weights and measures are creeping into actual use; and the perpetual recurrence of references to it in the news of the day foreshadows its coming. Previous to our recent national election, a map was published showing the distribution of the party votes in the several Congressional districts, on a scale of 1,000 votes to a millimeter. The strength of the starving Dr. Tanner was reported in kilos in last summer's newspapers; P. T. Barnum advertised the number of square meters of canvas provided to shelter his great moral show; M. de Lesseps announced in our principal cities, in metric terms, his plans for an inter-oceanic canal. (It is not intended to class these gentlemen together in other respect.) Our manufacturers occasionally receive a foreign order in metric terms; and in some kinds of business there are special reasons which favor the adoption of the metric system; so to them we naturally turnin looking for the signs of progress.

Apothecaries, for instance, have intimate relations with the sciences of chemistry and medicine, and their partial separation from other kinds of business is illustrated by their having had an Apothecaries' Weight of their own. The 1880 edition of the apothecaries' pharmacopœia, to be published some time hereafter, will be changed toward the metric system, as your committee explained a year ago. The committee in charge of the publication met in Washington last May, and determined that the pharmacopœia shall state ingredients by proportion chiefly, and that when an absolute weight is mentioned, it shall be in grams, followed by an equivalent in grains; but that no pounds, ounces, drachms, scruples, or pennyweights shall appear. This will naturally tend to the practical adoption of the metric system by druggists and physicians, who constitute a large and influential part of our population.

Another old table different from the measure used in general business was Surveyors' Measure, in which 10 chains made 1 furlong, and the chain (equal to 22 yards) was divided into 100 links, each equal to 7.92 inches. Surveying, and especially railroad surveying, is now very extensively done with a chain $33\frac{1}{3}$ yards long, so that $6\frac{2}{3}$ such chains make 1 furlong; the subdivision is into 100 feet, and the foot is divided into tenths, each equal to $1\frac{1}{2}$ inches, and hundredths, each of which is 4 per cent. less than the eighth of an inch. This plainly indicates that surveyors are bound to have decimal subdivision, and that they are not bound to the customary inch and yard. Prof. H. F. Walling, a member of this Society, wrote from Ohio, where

he was engaged in making county maps, under date of March 1, 1880: "My occupation here during the past year has more than ever made it apparent to me that, so far as land surveying and conveyancing are concerned, no great inconvenience would be experienced from an immediate change to the metric system, or, at most, but little more than continually arises from the existing variety of standards. It is very evident to me that the adoption of the metric system would very soon result in the saving of a vast amount of vexatious and unnecessary labor to all persons connected in any way with operations in land. . .

"I have frequently found deeds in which dimensions were given in chains and links, rods, feet and inches, and fractions of an inch, all in the same conveyance."

The meter has been made the unit of the triangulation of the New York State Survey, with regard to which your committee corresponded with the director, as reported four years ago.

Upon the charts of the Coast and Geodetic Survey metric linear scales have been printed, beginning with the report for 1876, issued during the year 1880. Your committee wrote to the superintendent in 1877, asking if there could be any objection to adopting this practice, and reported the fact to you Oct. 1877.

The Graphic Trigonometer, exhibited by Mr. Adams at the meeting of this society last October, was constructed to metric dimensions.

James W. Queen & Co. published, last year, continuous metric profile paper, with lines one millimeter apart. As this makes 25 lines to 1 inch, as nearly as such paper generally measures, it can be used, if desired, in connection with our old units. Its general adoption, by keeping the metric units before the eye, would tend to make the system familiar. The millimeter spacing is good, being midway between Plate A (20 lines to an inch) and Plate B (30 lines to an inch), both of which are already known to be convenient. It corresponds to Plate C. It is amusing to notice that this paper is sold by the *yard;* as it is already marked off according to the metric system, the time may come when it will be sold by the meter without remeasurement. The publishers state that they find an increasing demand for it; and they have just now published sheets of metric cross-section paper, with lines two millimeters apart, and every fifth and tenth line made heavier.

Several new tables containing metric equivalents have been published, the most noteworthy being "Molesworth's Metrical Tables," uniform with the same author's "Engineer's Pocket Book," and of conspicuous merit in many particulars, but based on the law of Great Britain, which differs from ours in two respects. The imperial capacity measures are entirely independent of ours; and Parliament has declared that a meter shall be taken as equivalent to 39.3708 inches, while our Congress has enacted that it shall be taken as 39.37 inches. The meter actually is 39.37043 inches, according to what is accepted as the best determination yet made. One of these is based on Captain Kater's determination for the old British yard destroyed by fire in 1834; one on Capt. Clarke's determination for the new British yard, established in 1855; the third is intended to be sufficient for business purposes without attempting scientific refinement. These differences of less than a thousandth part of an inch are unimportant in commercial transactions, but are sufficient to produce some annoyance in computation, especially in square and cubic measure.

Another point in regard to which uniformity is desirable is the practice of abbreviation. The following system of abbreviations, as initiated by the Swiss government and approved by the government of Italy, has been decided upon by the International Committee of Weights, sitting at Paris. The "Bulletin du Ministre des Travaux Publics," and some other French publications, adopt it:

Length	Kilometer	km.
	Meter	m.
	Decimeter	dm.
	Centimeter	cm.
	Millimeter	mm.
	Mikron (0.001 mm)	μ
Area	Square kilometer	km^2.
	Hektar	ha.
	Ar	a.
	Square meter	m^2.
	Square decimeter	dm^2.
	Square centimeter	cm^2.
	Square millimeter	mm^2.

Cubic measure..	Cubic meter	m^3.
	Stere	s.
	Cubic decimeter	dm^3.
	Cubic centimeter	cm^3.
	Cubic millimeter	mm^3.
Capacity	Hektoliter	hl.
	Dekaliter	dal.
	Liter	l.
	Deciliter	dl.
	Centiliter	cl.
Weight	Ton	t.
	Metric quintal	q.
	Kilogram	kg.
	Gram	g.
	Decigram	dg.
	Centigram	cg.
	Milligram	mg.

The increasing use of the metric system in professional literature is a symptom of progress which requires a retrospect of several years for reliable observation. To present it in definite shape, a count has been made of the linear scales upon the illustrations published in "Engineering," the London weekly, during the years of your committee's existence. The following table gives the result:

Year.	Number of metric linear scales.	Number of non-metric linear scales.	Total number of linear scales.	Per cent. of metric scales in the total number.
1875	38	169	207	.18
1876	74	320	394	.18
1877	37	214	251	.15
1878	79	262	341	.23
1879	99	335	434	.23
1880	67	210	277	.24

The last column imperfectly shows the change that is slowly and surely taking place in the relative use of the metric and non-metric measures; how great the relative use is, it does not show; for the drawings that are made and figured by the metric system are generally published in "Engineering" with the addition of a linear scale of feet, though frequently they do not have any metric linear scale; but it is very rarely that a drawing in feet has a metric scale added upon publication.

A more marked illustration may be found in the transactions of the American Society of Civil Engineers. During 1880, besides the discussion of interoceanic canal projects, considerable of which was in metric measures, there were published three other papers that were either written in the metric system or with duplicate metric and old values; the society also distributed copies of a report upon the Sao Francisco River in Brazil, written chiefly in meters with occasional equivalents in parenthesis. Previously to 1880 the use of the metric system in that society's transactions consisted of a few metric scales on the illustrations, and some references in the text where the metric were evidently subordinate to the old measures.

CURRENT DISCUSSION.

The discussion of the metric question continues brisk. Col. Sedgwick's decimal system, mentioned above as opposed to the metric, was presented to the American Society of Civil Engineers, May 19, 1880. Col. W. Milnor Roberts, past president of that society, now in the employ of the Brazilian government, writes in "Journal of the Franklin Institute," for November, 1880 (pages 24, 25), a letter in which he speaks of the recent introduction of the metric system into Brazil, and of its probable ultimate adoption by the United States. During the last year the American Metrological Society has published, in two volumes, its proceedings from December, 1873, to December, 1879. The Ohio Auxiliary Society of the International Institute has also published its proceedings from December, 1879, through July, 1880.

The Engineers' Society of Western Pennsylvania took up the subject at several meetings. Mr. William Kent opened the discussion with an instructive paper, March 16, 1880, which he seemed to think himself might be criticised as "straddling" the question; he humorously compared himself to Ensign Stebbins, who was "in favor of the law, but agin its enforcement." Lieut. F. A. Mahan read a paper May 18, 1880, explaining simply what the system is, and forcibly presenting the leading arguments in favor of its adoption. Mr. James Park is quoted as saying "that he didn't know anything about it, and didn't want to know anything about it." A brief notice of the debate is given in "Engineering News" of May 22, 1880. The written papers were printed in the

society's transactions. Lieut. Mahan's paper was also published in the "American Manufacturer" of June 11 and 18, 1880.

Mr. Greeley's remarks at the May meeting of the Civil Engineers' Club of the Northwest constitute a simple and brief presentation of the argument in favor of his resolution already quoted; they were published in the "American Engineer" for June, 1880, and contained the following reply to an objection:

"Mr. Coleman Sellers, whose opinion is entitled to respect, thinks the cost will be very great in machine shops and factories, and estimates it for a machine shop employing 150 men at something like $150,000. But in this he includes the entire change or removal of all patterns, taps, dies, thread cutters, and measuring apparatus of all sorts. Other gentlemen as competent to judge, and in charge of large works, think this wholly unnecessary, and believe that simple and convenient expressions will be found in metric terms for values which we now express in inches and fractions down to thirty-seconds without any change in the dimensions of the thing itself. It will not be necessary to change the width of a railroad track. The value of 4 feet 8½ inches is 1 435 m. The metric expression takes fewer figures and symbols. It will be known then, as now, as the 'common gauge.' No doubt the tendency would be towards dimensions expressed in even figures, but the change would be gradual, and attended with little cost."

At the first annual meeting of the American Society of Mechanical Engineers, Mr. Coleman Sellers read a paper entitled "The Metric System: Is it wise to introduce it into our Machine Shops?" It was published in the "Journal of the Franklin Institute," November, 1880; in the "Railroad Gazette," Nov. 26, 1880; in "Engineering News," Nov. 20 and 27; in the "American Architect and Building News" of same dates; imperfectly in the "Iron Age" of Nov. 11; and very likely in other places to your committee unknown. The interesting character of the paper, as well as its author's reputation entitles it to this wide circulation, which enables all who are interested to read and judge it for themselves. That Mr. Sellers has written this paper four years after the adoption of the Franklin Institute Report of 1876, is an encouraging item of progress, and excites curiosity as to what he will say in 1884. It may be remembered that in obedience to your vote of Nov. 17, 1875, your committee sent to the Franklin Institute, among other bodies, a letter saying: "That the numerous and very great obstacles in the way of this reform can be surmounted by conducting it in a deliberate and judicious way is proved by the history of the recent adoption of the metric system in Germany;" which it then proceeded to sketch very briefly, closing with a suggestion that that example had better be followed in this country. As it happened, France was not named in the letter. The reply received from the Franklin Institute in November, 1876, was accompanied by a copy of the report of a majority of their committee, to whom the letter had been referred, bearing, as the names of its signers, first, Coleman Sellers, second, W. P. Tatham, Chairman. That report was chiefly made up of fragments of French history, with brief allusions to irreligion, paternal government, the revolutionary calendar, etc. Most of its facts are to be found in John Quincy Adams' report, made in 1821, and it contained but little to show that its authors had learned of anything that occurred subsequently to that date, and certainly not the remotest allusion to Germany from beginning to end. In 1880, Mr. Sellers takes the trouble to say, with his compliments, that it was Mr. Tatham that wrote that report, and a prominent topic of his paper is the adoption of the metric system in the machine shops of Germany, upon which he dilates as fully as if the subject had the charm of novelty. He brings out in a strong light the fact that the complete adoption of the metric system means changing old standard sizes, and states what standard sizes are used in Germany for scales of drawings, for bar iron, for shafting, and for twist drills. His opinion is, that in point of convenience, these contrast unfavorably with the corresponding series now in use in the United States, though in another part of his paper he makes the general remark that some happy coincidences are found in the use of the metric system, as well as of the old weights

and measures. What he dwells upon most, introduces several times, and gives comparative tables for, is the system of screw threads for bolts and nuts. The Whitworth system, based on the English inch, being in use in Germany, it was found impracticable to change it; so they adhere to it still, but have slightly altered the nomenclature, which Mr. Sellers condemns in these words:

"Having given up the inch, the Germans formulate their threads per diameter. For the names of the bolts they must either retain their English names, and call a 25.4 mm. bolt one inch, or they must call it what it is, 25.4 mm.; but some call it 25 mm. and make it .4 mm. larger. This inch bolt has 8 threads per inch, and as the diameter, too, is 1 inch, it can be said to have 8 threads per diameter. A $1\frac{1}{8}$ inch bolt measures 28.5 mm.; it may be called 29 mm. size; it must be cut out of 29 mm. iron, the nearest merchant size, with a loss of $\frac{4}{10}$ of a millimeter. This loss does not seem much, but the dies which have to cut it off tell the story very soon. The Whitworth scale gives the same pitch to $1\frac{1}{8}$ and $1\frac{1}{4}$ screws, viz., 7 per inch. The exclusive metric shops call the one $7\frac{1}{8}$ threads per diamter, and the other $8\frac{3}{4}$, and yet they are practically the same, and must be cut with same combination of change wheels on the lathe. Here is a precious example of what comes from trying to harmonize two systems under one nomenclature. The screw system in general use is so good, it has been so long in use, its disturbance would shock so many interests, that it is unwise to give it up," etc.

That it would be feasible to give it up if there were good reasons for doing so, appears from a paper,* read by Mr. Coleman Sellers in 1874, in which the following passage occurs:

"I have said business men count the cost before making changes in matters of habit or use; but when they can be shown that they will be gainers by the change, they give in to it heartily. This same example of screw threads will serve as an illustration. Mr. Whitworth's system of screw threads was already introduced in all the principal workshops of Europe. and in many in this country. But a better system was presented to the Franklin Institute, a system based on such simple laws, that, given the formula with no existing original to copy, any careful workman can originate a given thread that will match those in use. After an exhaustive debate on the subject of its introduction by the various departments of our government, and a careful consideration on the part of our mechanical associations, it came to be adopted as the United States standard. It was adopted at considerable expense, because it was believed to be an improvement on existing practice. We have still to keep up our old taps and dies for repair work; but no mechanic has deemed the expenditure involved in the change other than judicious."

It was Mr. William Sellers who presented to the Franklin Institute this "better system." He was present by invitation at the meeting of the master car builders, in New York City, in December, 1879, when the subject of screw threads was considered, and it appeared that frequently bolts and nuts purporting to be of the Sellers standard were not interchangeable. Mr. Wm. Sellers said, among other things: "It seems to me that the trouble does not lie with the system of screw threads; no difficulty seems to exist there. The difficulty is the original one of what is an inch," etc. This is quoted from a tolerably full report in the "Railroad Gazette" of Jan. 2, 1880. For information on this subject, published during the past year, reference may also be made to a long editorial article in the "Railroad Gazette" of Jan. 9, 1880, and to the discussion in the meeting of the American Society of Mechanical Engineers, Nov. 5, 1880, reported in the "Iron Age" of Nov. 11, and to brief letters in "Engineering" of July 16 and 23.

One hundred and fourteen shipyard laborers from the Clyde recently arrived at Montreal on their way to Wynlock shipyard, at Detroit—all, the *American Manufacturer* says, under contract.

*The Metric System in our Workshops: Will its Value in Practice be an Equivalent for the Cost of Introduction? Read at the Chicago meeting of the American Railway Master Mechanics' Association, May, 1874, and published in the Journal of the Franklin Institute, June, 1874, and in the Railroad Gazette, Sept. 5, 1874.

SUGGESTIONS FOR PREVENTING LONDON SMOKE AND MAKING IT COMMERCIALLY AVAILABLE.

By W. D. SCOTT-MONCRIEFF, C. E., F. R. S. S. A.

From the "Journal of the Society of Arts."

It is sometimes difficult to account for sudden movements of popular opinion. When once they begin, an element of momentum seems to take the place of the previous inertia, and the new form of social force appears frequently to be directly proportionate to the one which preceded it. We are now in the midst of one of these movements of opinion that is not difficult to account for. The interest which at present attaches to the question of how best to obtain the blessings of an uncontaminated atmosphere, has arisen out of a state of things with regard to smoke and fog, that is recognized as dangerous to the whole community. The work of relating the means to the end has commenced in earnest, and there is every likelihood that, before long, the public will be put in possession of information as to how the problem is most likely to be solved.

Some apology is, perhaps, necessary on my part to those who are at present exerting themselves as specialists in this field of inquiry, for not having laid my proposals before them to the exclusion of other channels. I am sure, however, that if any one of those gentlemen were in my place, they would have thought twice before rejecting so favorable an opportunity as the one which has been presented to me. The Society of Arts has already identified itself with this important subject. I trust that further facts and information may be brought to light by this additional discussion, and that they may prove useful to the committees whose praiseworthy efforts are, at present, being exerted for the public good.

The present position of the question renders it far from easy to know how best to deal with it before a scientific audience, who are well informed. Materials which were important contributions a few months ago, have already been assimilated, and no longer lend themselves to the further elucidation of the subject. I trust, therefore, I may be permitted to confine myself to the special scheme which I propose, and I need not say with what pleasure it is that I do so, when I tell you that, although it has occupied my thoughts for years, this is the first occasion upon which I have addressed an audience on the subject.

I wish, first of all, to attempt to make clear to you in a few words what is the present aspect of the question, as regards the methods and apparatus employed.

The classification of the methods may be arranged as follows:

1. Burning bituminous coal at a single operation, by exposing it to the heat of the fuel previously ignited. It is unnecessary to say that this method embraces nearly the whole of the domestic consumption of Great Britain, and a great part of the commercial consumption as well.

2. Separating the gas from a cheap quality of coal, heating it in an apparatus known as a regenerator, and using it without the solid residue.

3. Separating the gas from the coal at a comparatively low temperature, adding the partly coked residue of a previous charge to the fuel in the furnace, and passing the gas through the burning mass.

4. Using coke as a basis, and passing gas through the fuel as a means of supporting its combustion, both coke and gas having been obtained from a gas company.

5. Using fuel from which a certain proportion of gas has been extracted, which is the special subject of the present paper.

As regards the apparatus, it naturally follows the classification of methods or systems, and would far exceed the compass of this paper to describe in any detail. It will be well, however, for me to

say something of the more familiar appliances which are in every-day use, and to remind you of certain fundamental principles that are common to the whole of them. As you are all well aware, the combustion of bituminous coal depends upon the combination of certain gases, and of carbon and ogygen at a high temperature. It is also familiar to you all, that the oxygen necessary for this combustion is obtained from the atmosphere we live in. One necessary feature of the process is the creation of a draught, which is obtained, as you all are aware, by the action of a heated column of air in a shaft or chimney. But this invariable accompaniment of combustion is, in the nature of things, associated with a movement, not only of the air, but of the gaseous elements of the fuel, and it is almost inconceivable that the necessary quantities of oxygen can be obtained without this element of rapid movement. The question comes to be then, whether or not the mean velocity of the air and gases necessary to supply the oxygen, is compatible with the time that must elapse in order to obtain the necessary chemical combinations at the point of sufficient temperatures, which is in the body of the fire itself.

Now in the case of freshly added bituminous fuel placed on the top of a burning mass, it is quite certain that the conditions of a draught are inconsistent with complete combustion; and this brings us to a consideration whether or not it is possible to consume bituminous coal perfectly at a single operation, and leads to doubt as to the possibility of using the first method successfully in any apparatus, however ingeniously it may be devised for the purpose. Certain proposed processes are sometimes so inconsistent with the operation of invariable natural laws, that a conclusion on the subject of their failure has the certainty of a complete induction. If an apparatus depended upon its success on the tendency of water to run up hill, as in the case of many of our London house drains, we should be safe to predict its failure. The matter, as regards the complete combustion of fuel at one operation, is not quite in this elementary category, but, to my mind, it is very near to being so.

I am sure many present will sympathize with me in the great difficulty of making clear to others matters that do not contain within themselves all the elements of a complete induction. The induction may be so far complete, as regards oneself, that the mind is forced to a definite conclusion, but the discrepancies may, nevertheless, be the very elements which go to form a popular belief in another direction. I do not know of any better way of illustrating my meaning than referring you to several well-known fields of invention which, at one time, seemed to be altogether open, but which have become gradually closed with the advance of scientific knowledge. For instance, in the early days of steam locomotion, there must have been many persons who thought it presumption on the part of certain engineers to oppose themselves to the principle of the atmospheric railway. It must have appeared to them that it was wrong to predict the failure of science in one direction whilst anticipating its triumphs in another. And yet, I have no doubt, that men did appreciate at that time what was practically a complete induction in their own minds, however difficult it may have been to convey their arguments conclusively to others. Now, I do not know of any problem, at first sight, which gives a greater promise of a simple solution than the burning of an ordinary piece of household coal. The elements of combustion not only seem available, but, up to a certain point, lend themselves readily to a partial solution of the difficulty. Nothing is more easy than to get a fire to burn in an ordinary grate, and nothing is more difficult than to get it to burn in such a way that no smoke shall escape up the chimney. To predict the failure of all appliances for all time coming to attain this object is, therefore, on the face of it, an apparently rash anticipation, and yet there is nothing in the scientific aspect of the problem that suggests any other conclusion to my mind. I am not so much inclined to this opinion because of arguments that present themselves readily as the result of experiments on a small scale, but more from those which may be gathered from the experience of persons engaged in the consumption of fuel on a large scale, where the opportunities for carrying out complete combustion are exceptionally favorable.

Taking the iron trade as a typical example, I may say that all experience in the direction of cleanliness and economy is tending rapidly towards a total abandonment of the attempt to burn bituminous coal at one operation. The appliance which perhaps presents the greatest exception to this rule is the blast furnace. The vast scale upon which the consumption of fuel is carried on in this apparatus, would of itself place it in an exceptional position as affording peculiar facilities for obtaining an intense and constant temperature. Even here, however, the operation is becoming, to a great extent, divided, and the utilization of the waste gases for heating the air stoves is of itself a proof that, even with all its peculiar advantages, the hot blast is unable to carry out complete combustion at one operation.

Here is an illustration of a blast furnace of a not very improved or modern type, but which is sufficient to show the immense advantage the apparatus has over anything that one can conceive of, in our present state of knowledge, in respect of a domestic appliance. The temperature is not only intense enough to melt iron, but it is maintained from one month's end to another with the skill and assiduity of trained workmen. The air is not only introduced in immense volumes by means of powerful blowing-engines, but is heated to a high temperature before it reaches the fuel. The artist has, I think, somewhat exaggerated the volumes of smoke escaping from the mouth of the furnace, but its presence at least shows he was conscious of its existence. Now, as a matter of economy, these waste gases are utilized in the modern practice of iron smelting, but if they exist at all under conditions so favorable to complete combustion, what shall we say of appliances that burn a few pounds of coal at a time under the charge of an overworked housemaid? I am not speaking now of perfect combustion, but only of that fair amount which is consistent with a smokeless chimney.

As regards other departments of the iron industry, the attempt to consume bituminous coal at a single operation is being altogether abandoned. The labors of Dr. Siemens, as embodied in his regenerative furnace, have gone far to bring about a change in the direction of scientific principles, and Mr. Price's furnaces, as now used at Woolwich Arsenal, are also an illustration of improvement that has taken place in the same direction. I shall have occasion to speak of these appliances presently. Now, without saying that arguments drawn from such channels are altogether conclusive, I must say, that along with other considerations, they go far towards the formation of an opinion that in cases where the scale of the consumption is smaller, success will be still more impossible of attainment. As regards the scale of appliances that come under the head of domestic apparatus, I believe that the problem of consuming ordinary bituminous coal at one operation will ultimately be abandoned altogether, but it is beyond all likelihood that it will ever be satisfactorily solved. A few years ago this opinion would have been looked upon as unreasonable. I have long been convinced that it is a sound one, and this belief is supported, not only by several eminent authorities, among whom I may number Dr. Siemens, but also by the whole tendency of the practical improvements which have been carried out in our great national industries. I believe it is capable of a theoretical proof; but even if this were wanting, I think I am justified in pointing to the present condition of our large towns as a demonstration of the failure of existing appliances. When the vast amount of invention which has been expended upon the problem of the complete combustion of bituminous coal at one operation is taken into account, and when it is considered that not one appliance has ever been altogether successful, I think there is a strong *prima facie* case made out against the practicability of the proposal. If I may be allowed to put the argument as near as possible in the form of a syllogism, with regard to domestic hearths, I might say all bituminous coal requires a high temperature steadily maintained for its complete combustion. Domestic fires are incapable of producing a high temperature steadily maintained, therefore domestic fires are unfit for the complete combustion of bituminous coal. To hold an opposite opinion with regard to the element of temperature is inconsistent with the facts, and to insist on the high temperature being continually maintained is to deprive every citizen of

his right to allow his fire to go down when the heat he obtains from it has become excessive. I might quote many authorities in support of these opinions. Even in the case of steam boilers, where skilled labor is available, and where a high temperature, evenly maintained, is an important point, Dr. Angus Smith shows clearly that it is heat that is required for the complete combustion of the fuel, and that the supply of air in sufficient quantities is comparatively easy. I will suppose the case of an absolutely perfect domestic appliance for the combustion of bituminous coal, and I will ask the inventor of it where the heat has to come from that is essential to the process, when the fire has been allowed to go almost out, and the housemaid adds fresh fuel.

So far, I have tried to put the matter before you as regards temperature, but a moment's consideration of the actual process of combustion will, I think, make it equally impossible to escape from the conclusion to which I have come, even as regards the supply of air itself. Burning coals depend for their incandescence upon the passage of air among their exposed surfaces. In an open brazier, it may pass in from all sides, and underneath as well. So far this is a most favorable condition, but as it passes through the burning mass the oxygen is consumed, and it is impossible to insure that the air does not reach some parts of the fuel in an exhausted state. I have here a simple illustration of my meaning. This common paraffine lamp is so arranged that a current of air passes in close contact with the flame from the wick, and the oxygen is consumed in its passage. I will now suppose that this piece of bituminous coal, which I place over the top of the funnel, holds an analogous place to that which it might assume in the most ingeniously constructed stove imaginable, that is to say, some point at which the air, which has already passed through the fire, reaches it exhausted of its oxygen. The temperature of the lamp flame is sufficient to produce an escape of gas, and upon passing my hand over the funnel this is proved by the pungent smell of the gaseous products. Now you will find, that although the gas is escaping, the conditions are altogether inconsistent with combustion of any kind whatever. Upon striking a match, and bringing it near the top of the funnel, you will see that it is instantly extinguished. I now take a piece of smokeless fuel, and place it over the funnel, instead of the piece of coal. It goes without saying that although there is no more chance of combustion in the one case than there is in the other, still no smoke escapes, and, as far as the atmosphere is concerned, no harm is done.

I might multiply arguments indefinitely; but as time is of importance, I must ask even the unbelieving to accept my conclusions in the meantime, and simply point out that if they are right, the idea of adapting domestic hearths to the complete combustion of ordinary bituminous coal may be abandoned at once and forever. If smoke were like certain gases that burst into flame at a low temperature when they escape into the air, there might be some chance of obtaining a satisfactory result. But the fact that it does not ignite, even in contact with a red hot piece of iron, shows how temperature, beyond the capacities of an ordinary hearth, is essential to its perfect consumption. I have here a list of the gases contained in ordinary coal:

	Manchester gas.	Gas as supplied to Houses of Parliament.
Hydrogen	52.71	41.71
Marsh gas	31.03	41.88
Carbon monoxide	4.47	4.98
Olefines	11.19	8.72
Nitrogen	—	2.71
Carbon dioxide	0.58	—
	100.	100.

Now, some of these gases combine with oxygen much more slowly than others, so that some of them, in the case of an apparatus depending upon a draught (and I know of none in the nature of a domestic appliance that does not depend upon a draught), would be half way up the chimney before the combination was complete.

If these conclusions are right, an immense amount of ground is cleared as regards the solution of the problem, because the knowledge of what will be successful is, in nine cases out of ten, arrived at by discovering what cannot be successful in the nature of things. The conclusion means in other words, either

that the use of ordinary bituminous coal must be abandoned altogether, or that some apparatus must be devised for domestic purposes, similar, on a small scale, to those which have been introduced in our great industries, more especially those in the iron trade, to which I have already referred. This brings us to speak of the second and third methods, and I shall do so in as few words as possible. I do not see how these can possibly be carried out, for the simple reason that on the large scale skilled labor and the means of maintaining a constant high temperature are essential features of complete combustion, and neither can possibly be present with any certainty in the case of domestic fires. Dr. Siemens has hit upon an ingenious plan, by which he makes use of the operations of gas companies to separate the operation of combustion, it may be, miles away from the point of domestic use. This is the fourth method I referred to. By burning coke with gas flames burning through it, he avoids the difficulties of separation as regards the consumer, and carries out a scientific system of combustion at the same time. I propose, however, instead of this, to use a modified condition of bituminous coal, and I will try to show the advantages of doing so. It might be presumption on my part to say that I am the discoverer of this sort of fuel, but I may say that, so far as I know, I am the first to bring it into public notice.

First, I may say that, with regard to anthracite coal, if the principle of smokeless fuel is once recognized and enforced the stone coal will fight its way, and be of great service, not only as a heating agent, but as a wholesome source of competition as well. It is as a means of saving our smoke and improving our light that I propose the fifth method, and I shall go on to describe it.

About ten years ago I made a series of experiments upon the separation of the process of combustion which led me to think very highly of the class of fuel to which I refer. I placed a small D retort in a common Cornish steam boiler, and by lowering the position of the fire bars, arranged an apparatus for the distillation of gas from the fuel in ordinary use, and after some time had elapsed, I discharged the gaseous contents of the retort into the furnace. In this way I secured practically complete combustion by a separation of the fuel into its constituent parts of solid carbon and hydro-carbon products. The semi-coke that resulted from this short distillation was practically smokeless, and I have since discovered that by treating it with water when hot, as in the case of coke, renders it still more smokeless. So far as I am aware, it is the most perfect fuel imaginable, as it has all the cheerfulness of ordinary coal, with none of the disadvantages arising from the creation of smoke.

I must now ask you to turn your attention to the present condition of London as regards its fuel, and to make an effort to realize how matters actually stand. Leaving out of question the coke which is consumed by the public, I want you to realize the fact that there are about four million tons of coal consumed in London every year. You may conceive of this, more readily, as a solid cube, with a base of about 200 yards, built square upon all sides, to the height of the cross on St. Paul's Cathedral. This is what is burned for the purpose of obtaining heat, in addition to the surplus coke sold by the gas companies. Bearing this in mind, I must now ask you to try to realize another quantity, viz., about 2,000,000 tons—used for the purpose of obtaining light. This would be represented by a cube about 140 yards at the base, built up to a height of 430 feet. All this vast quantity is passed through retorts, and, after a large amount of bad gas has been extracted from it, it is converted into cinders called coke. Now, it has entirely escaped observation that the gigantic appliances necessary for treating the one heap of coals on a long extraction, with bad results, is capable of extracting a small quantity from both heaps of coals on a short extraction, with good results both as regards gas and fuel. The fuel would be similar to that which resulted from the experiments I have referred to, the illuminating power of London gas would be approximately doubled, and the aniline dyes and ammonia, and other products of the process of distillation, must be doubled as well.

To those who may be ready to exclaim against the vast capital which will be required to carry out this operation, I will

now show you how it is that no additional plant is necessary in order to obtain this result. We will begin by a familiar illustration. Supposing one of the smaller gas companies were to begin to-morrow to advertise and sell coal from which only 3,000 cubic feet of gas had been extracted per ton. The fuel must be cheap to the consumer at 23*s* per ton, and thus, to start with, the company would recoup its outlay for coal, which we will suppose cost them on an average about 16*s*. per ton. But, in order to keep up its normal production of gas, so soon as a retort was discharged, it would simply need to be charged again. In this manner gas would be coming away from the retort all day long, just as formerly, with a slight loss of time to be allowed for the additional frequency of the charging. As, however, the gas under the proposed arrangement comes off much more rapidly than under the existing system, the supply at the end of the 24 hours would be in excess of that which is obtained from the long extraction, and in this way less and not more plant would be necessary to give the same quantity in a given time. But instead of bad 12-candle gas, they would have 20 or 24-candle gas to dispose of, with double the quantity of bye-products to the good in addition. What applies to the case of one small company would of course apply equally to the whole combined.

I have already trespassed on your time at considerable length, but as there are no doubt many here present who prefer an ounce of practice to a hundred weight of theory, I think it well to tell you that my scheme has already been carried out at Woolwich Arsenal when all other methods had failed to supply the establishment with sufficient light. When I say my scheme, I say so with an important limitation in this particular case, because when I went to explain the proposal to Mr. Wallace, who is one of the most scientific gas managers in the kingdom, I found he had already been in the habit of adopting it. Curiously enough, however, he had never generalized from the facts, and until I pointed out the wide applications of which it was capable, had not thought of it as a means of utilizing the smoke of our great cities. During the long winter evenings, the available plant at the Arsenal frequently falls short of the demands that are made upon it. Under ordinary conditions, the supply of 16-candle gas is just sufficient for the purpose of supplying light, and if we take the quantity of this to be, say 100 cubic feet per unit of time, then if 20-candle gas were substituted, the quantity of light would be increased proportionately, that is to say from 100 to 125, in terms of a photometric measurement. Now, not only is this result obtained, as regards the quality of the gas, by simply removing one charge of coals at the end of four hours and substituting a fresh one, but larger quantities of the better gas are obtained, and that for two reasons. First of all, the gas comes off in greater quantities per unit of time on an average short extraction than on an average long one; and the fuel used for heating the retorts, being greatly superior to ordinary coke, assists the operation still further. In this way, then, the superiority of the short extraction is proved in all directions. I have here a few specimens of the fuel. No. 1 represents an extraction of 3,000 cubic feet per ton; and if it were used in London, this city would be rendered practically smokeless. I must explain, however, that an experimental retort does not give a fair specimen of the fuel. Measurement by the meter is the only method of guessing at the amount of extraction; but this is by no means a satisfactory test of the equable character of the distillation. That is to say, that the 1½ cubic feet of gas which may come away from 1 lb. of coal in an experimental retort, although a satisfactory test of the extraction being at the rate of about 3,000 cubic per ton, may, nevertheless, have come to a great extent from the outer surface of the sample, leaving the interior both bituminous and smoky. In an ordinary extraction on the large scale, the fuel may be taken as smokeless and in every way suitable for domestic consumption.

Perhaps, the most pleasant way to conclude this paper would be to draw a picture of the present state of London—overcast, filthy, given to fogs, grievous to breathe in—with the London of the future, clear as the tops of the Surrey hills, if the fuel I have been describing were in universal use. I must ask you instead, however, to follow me through a

few figures which explain the financial bearing of my scheme upon the community generally.

First, then, as regards capital expenditure, I propose to take advantage of the existing plant of the gas companies. I find they are amply sufficient for the purpose.

Instead of taking 10,000 cubic feet of gas per ton from the coal, I propose to take 3,333 cubic feet, and to pass three times the quantity through the retorts, or in any other proportion that may be found most convenient. The result of doing so is startling.

The companies will have double the quantity of by-products they have at present in the shape of tar and ammoniacal liquids; the community will have 24-candle gas instead of 16-candle gas; the fuel resulting from the process will light readily, and it will make a cheerful fire that gives out 20 per cent. more heat than common coal; London would become a smokeless city.

In dealing with the figures, I shall take them roughly, but in such a way that by including a few outlying corporations they could be made absolutely correct.

I take the total annual consumption of coal in London to be 6,000,000 tons. Of this I take 2,000,000 tons to be the annual consumption of the gas companies. The total quantity of fuel used for general purposes I take to be 4,000,000 tons of coal and 1,000,000 of coke sold by the gas companies.

We shall now see what would be the result if we treat the whole of the 6,000,000 tons in the retorts on an extraction of less than three hours, instead of the six hours at present prevailing.

The total quantity of 16-candle gas consumed in London may be taken at 20,000,000,000 cubic feet. This would be at the rate of 3,333 cubic feet per ton upon 6,000,000 tons, the total quantity of coal consumed in London. The residual smokeless fuel would amount to 5,100,000 tons. Of this 1,000,000 tons would be required for the extraction of the gas, leaving 4,100,000 available for the general uses of the community. This has to be compared with the 4,000,000 tons of coal and the 1,000,000 tons of coke already referred to as consumed at present. Now, the smokeless fuel which results from an extraction of 3,333 cubic feet of gas per ton has a heating capacity fully 20 per cent. greater than common coal, and 10 per cent. greater than coke. This gives us the exact equivalents of the 5,000,000 tons of fuel at present in use.

So far the account, as regards the fuel available for the community, balances. We may now deal with the difference in value between 16 and 24-candle gas. As the value of the gas varies directly as its illuminating power, the calculation is very simple. If we take the average price of 16-candle gas to be 3*s.* 6*d.* per thousand cubic feet, we shall find the total value of the 20,000,000,000 consumed in London to be £3,500,000, but as we have by my scheme the same quantity of 24-candle gas, the value will be increased to £5,250,000; here then we have an annual sum of £1,750,000 to place to the credit of the system.

Turning now to the by-products: seeing the gas companies, by the new arrangements, would subject three times the quantity of coal to the heat of their retorts during the period when the tar and ammoniacal liquors pass off most rapidly, I do not think I am wrong in estimating the yield at double its present amount. Taking this upon the tar and ammonia to yield 3*s.* 9*d.* per ton of coal, we find the total value of these by-products to be, at present, on the supposed consumption by the gas companies of 2,000,000 tons of coal per annum, £375,000. This being doubled under my scheme, an additional sum of £375,000 must be placed to its credit.

But the basis upon which we have hitherto been arguing is that the gas companies under the proposed scheme are getting their coal for nothing. We have been supposing that the community become the purchasers of 6,000,000 tons of coal and hand it to the gas companies. At present London only pays for its general consumption on 4,000,000 tons of coal and 1,000,000 of coke. Let us now suppose that the companies pay the same sum annually that they do at present for their coals; if so, they would pay upon 2,000,000 tons, or an annual amount of £1,600,000, if their coals cost 16*s.* per ton. From this falls to be deducted the money they at present draw from their sales of coke, which, when taken at 6*s.*

per ton of coal carbonized under the existing system, still leaves a sum of £1,000,000, which they could afford to pay per annum for the use of the 6,000,000 tons of fuel as proposed in my scheme. We will now take the total payments of the community for their coal to be upon 6,000,000 tons, for which we will further suppose they pay at the rate of 16*s.* per ton first cost. This would amount to £4,800,000 per annum. From this has to be deducted the £1,000,000 contributed by the gas companies for the use of the fuel, also the £1,750,000 charged on the difference between the 16 and 24 candle gas already referred to, also the sum of £375,000 of additional income from the by products. This would leave a net sum paid by the community for its fuel under my scheme of £1,675,000. Under the present system they have to pay, say 16*s.* per ton on 4,000,000 tons of coal, and say 12*s.* per ton on 1,000,000 tons of coke. This makes in all the sum of £3,800,000 per annum. Here then we have a balance in favor of my scheme of £2,125,000 annually. This may be taken as the yearly value of London smoke, which I propose to convert into useful products by the plant at present in use.

I have only, in conclusion, to say one or two words about the efficiency of the scheme as regards the fuel. It lights easily, it gives off no smoke, it makes a cheerful fire, it gives out more heat than either coal or coke, it will be cheaper per heat unit than the coal at present in use, London would become a smokeless city, and all that would fall to be deducted from the sum of £2,125,000 per annum would be confined to a few items, such as the cost of additional workmen employed in charging the retorts, interest upon additional capital required for transit appliances, and the terms to be made with the gas companies for carrying out the scheme.

I have much pleasure in acknowledging the help I have received from Mr. Wallace, the gas manager at Woolwich Arsenal, and the valuable information obtained from Mr. Field's tabulated accounts of the London gas companies. So far as I am aware, my contributions to the *Builder* and elsewhere are the only writing on the subject of my proposal that has ever been made public. I should say, in conclusion, that I have no pecuniary interest whatever in the scheme I propose.

ROMAN BUILDING IN ENGLAND AND IN ITALY.

From "The Builder."

An interesting description of the masonry of the portion of Roman wall lately discovered in the excavation for the Fenchurch Street Railway Station has been sent to the daily papers by the engineer of the Great Eastern Railway. The top of the portion discovered was about 9 ft. below the surface, and the bottom 9 ft. lower, giving a total of 18 ft., which very fairly corresponds to what we have before had occasion to mention as a rough scale for the accumulation of *débris* on town sites, of about 1 ft. per hundred years. There are, however, several particulars of an unusually suggestive nature with regard to this wall. We need only slightly refer to its ponderous strength—9 ft. in thickness at its foundations—a strength which, before the invention of gunpowder, was enough to guarantee a long resistance to even a pertinacious attack.

But it was not on mass alone that the Roman builder depended for security. When we consider the details of the present portion of his structure, we shall see how much thought has been given to the production of stable and durable work. Of the character of the cement used we shall have a word or two to say, only now remarking that after a lapse of more than 1500 years the solidity of the work is such as to render its demolition —even when attempted course by course —a very serious affair. The courses of wall are, in the main, 6 in. courses of random rubble, in limestone and mortar. But the thickening of the wall, not being effected by batter, but by steps, involved the introduction of a material that would

afford a more level surface than rubble for the offsets—if we rightly understand Mr. Langley's expression, "projecting three inches." This material is afforded by what the account calls tiles, but which are really the Roman bricks, frequently found in ancient work in this country, and made and used to this day in Italy. These bricks are 17 in. long, 12 in. broad, and 1½ in. thick.

There can be no doubt that the Roman bricks were introduced in order to form plinths or level offsets, as three offsets on each side of the wall are thus finished. The value of the long flat form for bond is also to be remarked. The two upper layers, of three courses each, extended through the wall. The lowest layer, 18 in. above the foundation, was probably not far from the level of the soil. This course only extended 18 in. into the wall; the rubble being built on two layers of blocks of stone, each 9 in. deep, and about 2 ft. square. It will be very interesting to ascertain from what quarries the Romans brought the limestone to build the wall of London; and Mr. Langley will do good service to archæology, as well as to the kindred professions of the architect and of the engineer, if he will obtain an accurate analysis of the stone found, and aid in determining whence it was brought.

Under the stonework of the wall was a bed, composed of six layers of flint and clay, 2 ft., 6 in. deep. Whatever was the level of the soil, this, no doubt, must have been a sunk and buried foundation. There occurs a very remarkable parallel to the mode of preparing the foundation of the second city built on the site of Novum Ilium, in which cakes of clay were used as a sort of packing for the foundations. Between each course of flint in the London wall was a bed of clay about 1½ in. thick. This structure was carried down 3 ft. into a solid bed of gravel. It would seem as if the ancient builder was of opinion that, when protected from atmospheric effect, clay was reliable as a building material, and the existence of the wall confirms the truth of this opinion.

The Roman bricks are bright red, well burnt, and retain their form and sharp arrises. About the year 1844, during the construction of the railway from Gravesend to Rochester, specimens of Roman pottery were discovered, in which the bright red color, and smooth, sharp surface, were like those of Samian ware. But the simplicity in form of some of the articles was such as to render it highly improbable that they had been imported. Like the bricks, they must, we should conceive, have been British-made. One of the Gravesend vessels, more like the saucer of a garden-pot than anything else, but smooth and bright, had the word "graciscæ" on it in raised characters from an indented stamp. The Society of Antiquaries have not as yet explained this word. It seems to indicate the existence of some Roman earthenware manufactory in the valley of the Thames; and the red bricks in London wall seem to us to tell the same tale.

We now come to the question of the mortar. And here we would ask our readers to compare the perfect petrifaction of the lime used in the old Roman work in this country with the crumbling condition of the mortar in many of the ruins of 300 or 400 years later date. Who has not been struck with this in examining such a ruin as Kenilworth, or in making his way up the turret staircase of some long-deserted keep? If we compare the Roman mortar of the third or fourth century with the London mortar of to-day, what is the result? The architect shakes his head, but is unable to repress a smile at the question. "Yes," he says, "but look at the age of the one." Is that a satisfactory reply? We at once admit that a certain time is assignable during which well-prepared mortar gradually becomes more and more solid, more and more, to repeat the word purposely before used, petrified; but we do not think that, when a certain time has gone by, the process continues. Between a house of six weeks old and one of six years every one can perceive the difference. Go back to sixty years and you may, perhaps, say the same. From 60 to 600 we are not prepared to say what takes place. But as between, let us say 1,200 and 1,600 years, we do not think that at all events any solidifying process goes on. Things being alike—that is to say, the mortar being as well made by the castle builders of the twelfth or fourteenth century as

by the wallers of the third or fourth century, we think that any difference in solidity could not be expected to be in favor of the latter.

We conclude, then, that the builders of the Roman wall of London made use of British materials, to which they applied the patient forethought and thorough integrity of execution that characterize Roman work. They dug the clay of the valley of the Thames, and instead of moulding it into thick blocks hard to bake, and next to impossible to bake thoroughly through, they moulded it into flat 1½ in. plates, on which the vitrifying process could have full effect, and which are almost, if not quite, as durable as fire-brick. As to brick, then, there is no doubt. But how about the mortar? As to that, also, we have ourselves no difficulty. The Romans used British lime, whether burnt from the chalk from Gravesend or from some other and harder stone it is for the chemist to tell us; but they made it into mortar in the Roman method. What is that? a reader may ask. We have, we think, before now, mentioned in these columns what it was; but, if so, it may well bear to be repeated. It was the diametric opposite of the present English method. There are many builders and persons conversant with public works who can remember the immense care which Mr. Brunel bestowed upon his specifications, and the elaborate system of inspection by which he effected the practical application of his rules. No one, as far as our experience goes, in modern times, so labored to secure the greatest excellence of work. In fact, it is well known that what Mr. Brunel called rubble would be called ashlar by some of his contemporaries, and that the rigidity with which his orders were carried out made it by 10 per cent. or 20 per cent. more costly to execute his designs than those of some of his brethren. Mortar, of course, exercised much of his care, and the mortar that he used was mixed hot from slacking the lime. If any remained to the next day, it was to be thrown away. Such was the specification; and although that was an extreme case, we apprehend that nine builders out of ten would say, if it erred at all, it erred on the right side.

In Italy an opposite view is taken, and an opposite method is adopted. The first practical preparation for building in that country is to dig a large oblong square pit, into which the lime is thrown when burnt, and covered with water. It is thought desirable to throw in at once all the lime that will be required for the building, and the longer it is before it is used the better it is considered to be. It forms a dense paste, which is taken out with a spade and mixed with sand or pozzuolana as required. It is usual to keep it moist, but we have never heard of or seen any thrown aside for any cause at all. The magnificient character of the work done with this mortar is well known. The Italians of many districts are born masons. Where we should call in the carpenter, and rig up a shore, a center, or a set of props, the Italian builder runs up a temporary wall. He saves the cost of wood, for he can use the stone over again; and his temporary work, if required, will last almost as long as his permanent work. In the cases, which are far from uncommon, of damage to building from earthquake, the wonderful celerity with which they are repaired is quite a phenomenon. Again, many of the Italian roofs are made of a species of mortar, a mixture of lime and clay, beaten for a week or ten days incessantly with clubs or mallets. The surface is quite watertight, a condition by no means to be obtained by English mortar. Again, for plasters of all kinds, down to the smooth surface which lends itself to the rapid brush of the frescoe painter, the excellence of the Italian lime, notwithstanding the wide geological range from which the limestone is taken, is something that is unattainable in England. It is all very well to say that the genius of the English school does not tend to work in fresco; there is something more than that. The English artist has not the opportunity of exercising himself by that most artistic use of his implements.

We recently saw a very remarkable illustration of the difference effected in the same material, and that, too, a cement, by the mode of treatment. We know an artist of rare patience and skill in the restoration of broken china. We know of a dragon vase, once fractured into twenty-five pieces, and of a china

plate, shivered into nearly forty bits, that are now on their owner's shelves, without any visible mark of a crack. The cement that was used is that known as the "Mend-all cement"; but, of course, the skill goes for much more than the choice of material.

The artist in question, however, has long been careful to procure the smallest possible bottles of the cement; and that for the following reason: The material is prepared for use by dipping the bottle containing it into hot water. It then becomes fluid, and is easily applied to the edges to be joined, the fragments being themselves kept in hot water, and taken out and wiped before being cemented and put into place. If a large number of mends are made, and the whole affair gets out of shape—which it is very difficult in that case to avoid—the mended article is again put in very hot water, when it comes to pieces at once. Each piece has to be carefully wiped and re-cemented.

The objection to large bottles of cement is this—hitherto a perfectly empirical one:—After the cement has been liquefied and cooled a certain number of times, it becomes refractory. It no longer liquefies easily, if at all. It makes bad mends, or is altogether useless.

To this long-observed fact, a second observation has been added, within the last few days, which is highly significant. The bell of a "Queen's" reading lamp, which had a large piece broken out of it some years ago, was mended by the artist in question, and has been in nightly use ever since. After the fashion of mended things, this glass shade has outlived its more robust brothers. But the line of junction was visible, and the repairer thought that it would be an improvement to wash the bell, remove the old cement, and re-cement it. The bell, however, thought otherwise. To the surprise of the operator it laughed at the hottest water, and absolutely refused to allow the crack to re-open, or the cement in any way to soften or dissolve.

This phenomenon is worthy of reflection. It is impossible to disconnect it from the behavior of the cement in the bottle. The shade of a queen's lamp does not get so hot as to burn one's fingers, but it gets warm. The mended individual has thus been warmed and allowed to cool at least a thousand times. At what stage in the process the chemical change was complete it is impossible to tell. Very likely in twenty or thirty days. But slowly and gradually the cement has so parted with some element of solution as to vitrify, or, at all events, to unite itself with the glass in a union indissoluble by the agency of hot water, the original solvent of the preparation.

We cannot bake walls, unless it be by selecting very hot weather for their construction. On the other hand, we can avoid that soaking of the bricks, if rain happen to come on during the process of building, of which no notice is now usually taken. We know of one costly building, of which the color is permanently and entirely ruined by this neglect. Our object is to induce the Royal Institute of British Architects, the Institution of Civil Engineers, or others whom it may concern, to investigate this important fact of the behavior of lime or other cement. What is the effect of time on their cohesive force? Should time be allowed to elapse before the use, as is the case in Italy? Should it be combined with repeated rise and fall of temperature, as in the case of the Mend-all cement and of the lamp-glass that we have cited? Will an exposure of a certain duration to a steady heat have the same effect? And, if so, what heat, and for how long applied? These are questions of primary interest to the architect. Their solution may place a new material within his grasp. He may be enabled to rear those egg-shell domes which the imagination of Bulwer fashioned for the homes of the "Coming Race." We can never tell how far a new idea may carry us. We strongly suspect that the builders of the earliest bridge over the Tiber, or of the walls of Rome—certainly that the builders of the Roman wall of London—had a much clearer insight into the relation between the time spent in preparation and the permanent durability of work, than has any writer or lecturer on structures at the present day. We are not now speaking of those "Jerry builders" of whom a contemporary justly observed, *àpropos* of this very discovery of a Roman relic, that the Romans would have thrown them from the Tarpeian rock. We are speaking of thoughtful

and experienced men. We are quite sure that Isambard Kingdom Brunel, were he now alive, would respond to our words by an elaborate series of experiments; and that if the result confirmed the practice of the Italian builder, he would then and there have re-drawn his specifications. We know not on whom now to place confidence for an equally earnest and practical desire to reply to such a question, but we trust that each and all of our friends who have the opportunity will do their best to aid in the formulation of the answer.

THE MANUFACTURE AND USES OF CAST STEEL.

From the "English Mechanic."*

THE first question which the user of cast steel has to answer is, to decide which of the three great methods of making steel produces a material best adapted to his own wants. Sir Henry suggested to you, in his admirable lecture, that Bessemer steel would answer every purpose for which steel is used, with the possible exception of the steel required to make Canadian axes. There can be no doubt whatever that the Bessemer steel, of which Sir Henry gave you the first analysis, would have made an excellent Canadian axe had it contained the proper quantity of combined carbon. The only doubt I feel is whether it could be produced of sufficient soundness without so large a percentage of waste as not to raise the price beyond that at which crucible cast steel for Canadian axes is now sold. I must confess that my experience of Bessemer cast steel would incline me to say that it could not. In spite of the prejudice that exists among consumers of steel, such is the competition of the present day that I am sure that if steel could be produced of as good quality, and cheaper in price, by any other process than that of melting in crucibles, the present melting furnaces of Sheffield would rapidly melt away into old bricks and mortar. I venture to express the opinion that the reason that high-class Bessemer steel is not as good as high-class crucible cast steel is because the former cannot be made sufficiently sound without the admixture of silicon and manganese, both of which substances are injurious to cast steel for most purposes. I fear that the advantages supposed to be derived from the use of manganese in the manufacture of cast steel are, to a large extent, illusory. I have frequently conversed with consumers of steel who knew the trade before the introduction of spiegel iron into Sheffield, and it is remarkable how many of them expressed the opinion that the crucible cast steel now in use is not as good as it was when they were young.

To obtain sound ingots from high-class iron it is necessary to boil the steel for nearly half an hour after it has become fluid, and then to allow it to cool down to a certain temperature before it is poured into the mould. The process is called "killing" the steel, and it is an axiom amongst them that the higher the quality of the steel the more "killing" it takes. It is in this part of the process of crucible cast steel-melting that the virtue of the process consists; and the cost and quality of the cast steel produced depend in a large degree upon the skill brought to bear upon it. My theory is that the reason why high-class steel has to be so long boiled is to get rid of its occluded gas, which would otherwise produce bubbles or "honeycombs" in its attempts to escape. The addition of a portion of scrap steel much assists the "killing," as would naturally be the case if we suppose the scrap, which has been melted before, to have parted with its occluded gas in the first melting. That the presence of manganese or silicon helps largely to "kill" the steel, I account for on the theory that the carbonic acid unites with the manganese or silicon, and becomes a solid. So far, my theory appears to hold water pretty well; but when I come to the fact that low-quality cast steel—for example, steel melted from Bessemer rail scrap, which contains from 0.15 to 0.05 per cent. of phosphorus—does not require any "killing" at all, and may be poured into the mould as hot as the strength of

* Abstract of a lecture by Mr. Henry Seebohm.

the crucible will allow, I am obliged to admit that I am not chemist enough to give you an explanation of the cause. The main point which I wish to impress upon you is that the much-maligned rule of thumb, which insists upon the superiority of crucible cast steel over Bessemer steel for certain purposes, may have a scientific basis, and must not be hastily set aside as prejudice.

Having decided by what process the steel is to be made, the next question that should come before the consumer of cast steel is the percentage of carbon which he wishes it to contain. When I first began business, the "temper" of steel, or the percentage of carbon which it contained, was concealed from the consumer. The following is a list of the most useful "tempers" of cast steel:

Razor Temper ($1\frac{1}{2}$ per cent. carbon).—This steel is so easily burnt by being overheated that it can only be placed in the hands of a very skillful workman. When properly treated, it will do twice the work of ordinary tool steel for turning chilled rolls, &c.

Saw File Temper ($1\frac{3}{8}$ per cent. carbon).—This steel requires careful treatment; and although it will stand more fire than the preceding temper, should not be heated above a cherry-red.

Tool Temper ($1\frac{1}{4}$ per cent. carbon).—The most useful temper for turning tools, drills, and planing-machine tools in the hands of ordinary workmen. It is possible to weld cast steel of this temper, but not without care and skill.

Spindle Temper ($1\frac{1}{8}$ per cent. carbon).—A very useful temper for mill-picks, circular cutters, very large turning tools, taps, screwing dies, &c. This temper requires considerable care in welding.

Chisel Temper (1 per cent. carbon).—An extremely useful temper, combining, as it does, great toughness in the unhardened state with the capacity of hardening at a low heat. It may also be welded without much difficulty. It is consequently well adapted for tools, where the unhardened part is required to stand the blow of a hammer without snapping, but where a hard cutting edge is required, such as cold chisels, hot salts, &c.

Sett Temper ($\frac{7}{8}$ per cent. carbon).—This temper is adapted for tools where the chief punishment is on the unhardened part, such as cold setts, which have to stand the blows of a very heavy hammer.

Die Temper ($\frac{3}{4}$ per cent. carbon).—The most suitable temper for tools where the surface only is required to be hard, and where the capacity to stand great pressure is of importance, such as stamping or pressing dies, boiler cups, &c. Both the last two tempers may be easily welded by a mechanic accustomed to weld cast steel.

Next to quality, by which is meant the percentage of phosphorus, sulphur, silicon, manganese, &c., the most important thing is temper, or percentage of carbon. For many purposes, indeed, temper is of more importance than quality. Nothing is more common than for steel to be rejected as bad in quality because it has been used for a purpose for which the temper was unsuitable.

When the steel has arrived in the user's hands, the first process which it undergoes is the forging it into the shape required. This process is really two processes. First, that of heating to make it malleable, and second, that of hammering it, while it is hot, into the required shape. The golden rule in forging is to heat the steel as little as possible before it is forged, and to hammer it as much as possible in the process of forging. It is impossible to lay down exact rules for each of the thousand-and-one tools in which steel is used. The treatment of each tool, in each process which it undergoes, is an art that can only be learnt by practice, and can no more be taught in a lecture than the arts of skating, riding, or swimming. The utmost that can be done is to lay down certain general rules, and, if possible, to attempt some scientific explanation of them, to elevate them above the despised position of rules of thumb. The worst fault that can be committed is to overheat the steel. When steel is overheated it becomes coarse grained. Its silky texture is lost. If the temperature be raised above a certain point, the steel becomes what is technically called "burnt," and the amount of hammering which it would require to restore its fine grain would reduce it to a size too small for the required tool, and the steel must be condemned as spoilt. Overheating in the fire is the primary cause of cracking

in the water. The quality of steel may be so bad, *i. e.*, the percentage of phosphorus in it may be so high, that the amount of heat absolutely necessary to forge it at all into the shape required may cause it to crack in hardening. One of the principal reasons why a high-class quality steel is required for certain purposes is that it will suffer less injury by being heated to a greater degree, or by being heated and reheated a greater number of times than inferior qualities of steel. In heating steel the happy medium must be attained between heating it too much and too little, and between letting it lie too long "soaking" in the fire, and not "soaking" it through. Both the degree of temperature and the duration of the heat must be carefully watched. Some tools, such as circular cutters, files, &c., after they are forged into the shape required, must have teeth cut into them. Before this can be successfully accomplished, a preliminary process has to be gone through. The process of hammering or forging the steel into the shape required has hardened the steel to such an extent as to make the cutting of teeth into it impossible or difficult. It must consequently be annealed. This process, like the preceding one, is a double process. The steel must be reheated as carefully as before, and afterwards cooled as slowly as possible. Many tools are only required to be hardened on a small part of their surface, and it is important that the unhardened parts should possess the maximum amount of toughness, the minimum amount of brittleness, that can be attained. These tools must also be annealed after they are forged. The process of annealing, or slow cooling, leaves the steel coarse grained, gives it its maximum of ductility, and causes it, in fact, to approach the properties of lead.

We now come to the culminating point in our manufacture, where the invaluable property which distinguishes steel from wrought iron or cast metal is revealed, a process by which we suddenly change our steel from lead into glass—the process of hardening. In this, as in all other processes which steel has to undergo, we have to run the gauntlet of fire. We do so, however, at greater risk than heretofore. The forging of our tool is finished; it has taken the final shape to which we have destined it, and whatever injury we inflict upon it by overheating is irrevocable, and can no more be cured or mitigated by the hammer. We must, therefore, double and redouble our care, lest the temperature be raised above the point necessary to insure the required hardness. The part of the tool required to be hardened must be heated through, and heated evenly, but must on no account be overheated. Our tool must be finished at one blow—the blow caused by the sudden contraction of the steel produced by its sudden cooling in the water; and if this blow is not sufficient to give to the steel a fine grain and silky texture; if, after the blow is given, the fracture, were it broken in the hardened part, should show a coarse grain or dull color, instead of a fine grain or glossy luster, our tool is spoiled, and must be consigned to the limbo of "wasters." The special dangers to be avoided in hardening each kind of tool must be learnt by experience. Some tools will warp or "skeller," as we say in Yorkshire, if they are not plunged into the water in a certain way. Tools of one shape must cut the water like a knife, those of another shape must stab it like a dagger. Some tools must be hardened in a saturated solution of salt, the older the better, whilst others are best hardened under a stream of running water. Most tools have a tendency to water-crack if taken out of the water before they are absolutely cold. Where the edge of a tool only is hardened, care should be taken to move it up and down in the water, so as continually to change the water level, lest the tool should crack at the water level. Steel contracts in hardening, and contracts most when it is cooled most suddenly. If the hardened part join on to the unhardened part too suddenly, the steel at the junction will be in a dangerous state of tension which predisposes it to crack, and it is wise to lessen the amount of tension by distributing it over as great an area as possible. In some tools where the shape necessitates a great difference in the rapidity of cooling, it is wise to drill holes in the thicker parts where they will not interfere with the use of the tool, holes which are made neither for use nor ornament, but solely with the view of equalizing the rapidity of the

cooling of the various parts, so as to distribute the area of tension, and thus lessen the risk of cracking in hardening.

Our difficulties are not quite over when the process of hardening has been successfully accomplished. Our steel was originally lead; it has now become glass. But we do not want glass: it is too brittle; we want whalebone. An unhardened knife would bend like wrought iron; a knife hardened only would break like cast metal. We want both qualities combined—the bending quality of the iron and the resisting quality of the metal. We want the elasticity of the whalebone. Our knife must spring like —like what?—like *steel*. To attain this our tool must pass through the final process—that of tempering.

If you heat a piece of hardened steel slightly, and allow it to cool again, it becomes tempered. It suddenly changes from glass to whalebone: and in the process of changing its nature, it fortunately changes its color, so that the workman can judge by the hue of the color the extent of the elasticity which it has acquired, and can give to each tool the particular degree of temper which is most adapted to its special purpose. The various colors through which tempered steel successively passes are as follows: Straw, gold, chocolate, purple, violet, and blue. Of course, in passing from one color to another, the steel passes through the intermediate colors. It really passes through an infinite series of colors, of which the six above mentioned are arbitrarily selected as convenient stages.

It must be borne in mind that the elasticity of tempered steel is acquired at the expense of its hardness. It is supposed that the maximum of hardness and elasticity combined is obtained by tempering down to a straw color. In tempering steel regard must be had to the quality most essential in the special tool to be tempered; for example; a turning tool is required to be very hard, and is generally taken hot enough out of the water to temper itself down to a degree so slight that no perceptible color is apparent, whilst a spring is required to be very elastic, and may be tempered down to a blue. If you ask me to give you a scientific explanation of the process of tempering steel, I must confess my absolute ignorance. I have no more idea why it is so than the man in the moon, and the utmost I could do would be to mystify you in talking unintelligibly about molecular rearrangement and crystalline transformations. Hardening in oil is another mode of treating steel, which appears to a certain extent to attain by one process the change from lead into whalebone without passing through the intermediate glass stage, and is of great value for certain tools.

There are many kinds of steel to which your attention should be called, but which can only obtain from me the briefest mention. A special steel for taps, called mild-centered cast steel, is made by converting a cogged ingot of very mild cast steel, so that the additional carbon only penetrates a short distance. These bars are afterwards hammered or rolled down to the size required, and have the advantage of possessing a hard surface without losing the toughness of the mild center. Another special steel, somewhat analogous to mild-centered cast steel, is produced by melting a hard steel on to a slab of iron, or very mild steel heated hot enough to weld with the molten steel, so that a bar may be produced, one half of which is iron and the other half steel, or three-fourths iron, and one-fourth steel, as may be required.

A third kind of special steel, which is used for turning tools for chilled rolls, magnets, and some other purposes, is made by adding a certain percentage of wolfram, or, as the metal is more generally called, tungsten, sometimes with and sometimes without carbon, sometimes to such an extent that it can be used without hardening in water. Special steel of this kind is the finest grained that can be produced, but it is so brittle that in the hands of any but exceptionally skilled workmen it is useless. The addition of chromium, instead of wolfram, has somewhat the same effect.

It is much to be regretted that no easy method of testing cast steel has been invented. The amount of breaking strain and the extent of the contraction of the area of the fracture are all very well for steel which is not hardened, and not required to be used in a hardened state, but for hardened and tempered steel it is practically useless. It is very difficult to harden and temper two pieces

of steel to exactly the same degree. A single test is of comparatively small value, as a second rate quality of steel may stand very well the first time of hardening, but deteriorates much more rapidly every time it is re-hardened, than is the case with high-quality steel. Nor am I at all sure that the breaking strain is a fair test of the quality of steel. For many tools the capacity to withstand a high amount of breaking strain slowly applied is not so much required as its capacity to withstand a sudden shock. The appearance of the fracture is very illusory. The fineness of the grain and the silkiness of the gloss is very captivating to the eye, but it can be produced by hammering cold. The consumer of steel may be enraptured, if he be of a poetical turn of mind, by the superb fracture of a bar of steel, reminding him of a picture by Ruskin of the aguille structure of the Higher Alps; but, after all, this is only a dodge, depending upon the inclination of the axis of the revolving hammer to the plane of the anvil. The practical consumer of steel must descend from the heights of art and science, and take refuge in the commonplace of the rule of thumb, and buy the steel which his workmen tell him is full of "nature" and "body."

EXPERIMENTS ON THE STRENGTH AND STIFFNESS OF SMALL SPRUCE BEAMS.

By F. E. KIDDER.

From Proceedings of the American Academy of Arts and Sciences.

THE object of the following experiments was to determine the Moduli of Elasticity and Rupture in small beams of white spruce (*Abies alba*); and such other information as might be derived from the data obtained.

The machine used for the purpose consists of two solid wooden frames, carefully leveled and placed forty inches apart. Upon the top of each frame is placed a movable plate of iron, which is carefully adjusted so that the two plates shall be directly opposite each other, and exactly forty inches apart between the faces. These plates form the supports for the beams.

The loads were applied by means of a scale pan suspended from a three-quarter inch bolt, which rested upon the center of the beam. By means of an iron strap suspended from a horizontal beam placed above the test piece, and resting on two screws, the bolt from which the load was suspended could be raised from or lowered upon the test piece as easily and gradually as could be desired.

The deflections of the beams were measured by means of a micrometer screw, reading to one ten-thousandth of an inch. As the bolt from which the load was suspended rested on the center of the beam, it was necessary to measure the deflections at a distance of one-inch from the center; but the deflections used in calculating the values of the Modulus of Elasticity were corrected so as to give the deflection at the center, supposing the curve assumed by the beam to be the arc of a circle; from which, in fact, it deviates but little under such small loads. In reading the micrometer, the principle of electrical contact was taken advantage of.

The greatest errors liable to occur in using the machine are as follows:

In measuring the deflections, one ten-thousandth of an inch. In the breaking load, possibly one pound; but in the small loads there could be no appreciable error. In measuring the dimensions of the test pieces, two thousandths of an inch.

The experiments were conducted with the utmost care, and every possible precaution was taken to prevent errors.

In arranging for the experiments, and while making them, the writer was greatly assisted by Mr. Holman of the Institute, to whom he extends his acknowledgements.

The pieces of wood experimented on were sawn from a spruce plank that had been cut in eastern Maine in the spring of 1880, and the following summer

shipped to Boston, where it had lain in the open air until it was cut up in October. The pieces were carefully planed to an approximate size of one and a-half inches square and four feet long.

They were nearly all straight-grained and had but few defects, and in testing the beams they were placed so that the defects should have the least possible effect upon the strength of the beams. The exact dimensions of the test pieces are given in Table I:

TABLE I.

No. of Test Piece.	Clear Span. l.	Breadth. B.	Depth. D.	E.	E_1.	R.	Center breaking weight for beam $1'' \times 1'' \times 1'$.
	ins.	ins.	ins.	lbs.	lbs.	lbs.	lbs.
1	40	1.475	1.450	1,731,000	1,657,000	11,380	632
2	"	1.445	1.520	1,556,000	1,528,000	10,330	574
3	"	1.469	1.448	1,765,000	1,732,000	10,710	595
4	"	1.420	1.498	1,736,000	1,636,000	10,830	601
5	"	1.450	1.485	1,688,000	1,578,000	11,980	665
6	"	1.480	1.440	1,795,000	1,686,000	11,040	613
7	"	1.464	1.460	1,682,000	1,561,000	10,570	587
8	"	1.420	1.480	1,647,000	1,556,000	11,280	626
9	"	1.460	1.460	1,704,000	1,638,000	11,180	621
10	"	1.441	1.460	1,616,000	1,550,000	12,440	691

In making the experiments, each beam was first subjected to a load of thirty pounds, and the deflection noted. The weight was then left on the beam for a period of time varying from one to four, and in one case forty-four hours, and the deflection again noted. The load was then removed from the beam and the set noted, after which the beam was allowed a certain time to recover from the set.

After the piece had returned, or at least nearly returned, to its original position, it was subjected to a load of forty pounds in the same manner.

Table II. gives the deflection of each piece under the loads of thirty and forty pounds, both immediately after the weight was applied and after it had rested upon the beam the length of time designated.

TABLE II.

No. of Test Piece.	Weight W.	Time applied.	Deflection Δ	E.	Weight W.	Time applied.	Deflection Δ	E.
	lbs.	h. m.	ins.	lbs.	lbs.	h. m.	ins.	lbs.
1	30	0 00	0.0610	1,744,000	40	0 00	0.0826	1,719,000
"	"	2 25	.0630	1,689,000	"	3 30	.0873	1,627,000
2	30	0 00	.0616	1,536,000	40	0 00	.0801	1,576,000
"	"	1 45	.0639	1,481,000	"	3 00	.0842	1,499,000
3	30	0 00	.0606	1,774,000	40	0 00	.0815	1,757,000
"	"	1 00	.0610	1,759,000	"	1 00	.0840	1,705,000
4	30	0 00	.0582	1,725,000	40	0 00	.0765	1,748,000
"	"	2 25	.0616	1,627,000	"	3 20	.0813	1,645,000
5	30	0 00	.0580	1,740,000	40	0 00	.0774	1,637,000
"	"	2 30	.0618	1,630,000	"	44 15	.0874	1,527,000
6	30	0 00	.0605	1,792,000	40	0 00	.0803	1,799,000
"	"	3 00	.0639	1,697,000	"	5 12	.0862	1,676,000
7	30	0 00	.0624	1,683,000	40	0 00	.0833	1,682,000
"	"	3 00	.0663	1,584,000	"	16 00	.0911	1,538,000
8	30	0 00	.0632	1,645,000	40	0 00	.0839	1,650,000
"	"	4 15	.0666	1,561,000	"	16 30	.0894	1,552,000
9	30	0 00	.0619	1,701,000	40	0 00	.0823	1,707,000
"	"	1 30	.0643	1,638,000	—	—	—	—
10	30	0 00	.0661	1,614,000	40	0 00	.0881	1,618,000
"	"	2 00	.0691	1,544,000	"	1 15	.0915	1,556,000

The values of the Modulus of Elasticity calculated from these deflections are also given. The Moduli of Elasticity obtained from the deflection of the beams immediately after the weight was applied have been denoted by E, and those obtained from the deflection of the pieces after the weight had been applied one or more hours, by E_1. Table I. gives the values of E and E_1 for each piece, obtained by taking the average of the values given in Table II.

The values of E were computed by the formula $E=\frac{Wl^3}{4\triangle BD^3}$, in which W denotes the weight in pounds producing the deflection; l the clear span in inches; $\triangle$ the deflection of the beam at the center; B the breadth of the beam, and D the depth, both in inches.

After all the beams had been treated in this way, piece No. 3 was again put in the machine and subjected to a load of 100 lbs., which was allowed to remain upon the beam for about two hours, the deflection being measured directly after the weight was applied and just before it was removed. The beam was then allowed a certain time to recover its set. In two cases, the beams, after having been subjected to a load of 100 lbs., finally returned to their original position, and it appeared probable that all would have done so had sufficient time been allowed for the purpose.

After the piece had nearly recovered from the effects of the load of 100 lbs., a load of 150 lbs. was put on the beam, and gradually increased until the breaking point was reached.

The remaining pieces were tested with a load of 100 lbs. in the same way, and then subjected to a load of 400 lbs. for one or two minutes, for the purpose of getting the deflection under that load, and immediately after subjected to the full load of 500 lbs., which was gradually increased until the piece broke. As the load approached the breaking weight, it was increased by the addition of only one or two pounds at a time, so that the breaking weight could be obtained with sufficient accuracy. In fact, the breaking weight is so much modified by the time occupied in breaking the beam, that it is difficult to ascertain exactly what it really is. For any load over three-fourths of what is called the breaking weight would, probably, break the beam if applied long enough.

Table I. gives the values of the Modulus of Rupture of each piece, computed by the formula $R=\frac{3}{2}\frac{Wl}{BD^2}$, in which R denotes the Modulus of Rupture; W the breaking weight of the beam, and the other letters have the same significance as in the formula for E. The load which would break a beam of the same wood, one inch square and one foot between supports, if applied at the center, is also given in the same table. This load is one eighteenth of the Modulus of Rupture.

When the weight of 400 lbs. was applied to piece No. 7, it immediately cracked at a knarl in one of the lower edges, about three-fourths of an inch from the center of the beam. As it was thought that the beam would soon break entirely, the load of 400 lbs. was allowed to remain on the beam; but at the end of one hundred hours the deflection had only increased 0.2224 inches, and as it was evident that it would, at that rate, take a long time for the beam to break, the load was then gradually increased until the piece broke at 550 lbs., giving a Modulus of Rupture considerably above the average. It was noticed in this beam that the deflections under the loads above 500 lbs. were considerably greater than in the other beams under the same loads.

Piece No. 5 gave a very high breaking weight, and broke very suddenly, more like the harder kinds of wood. The fracture was very perfect, the upper half of the fibers being very evidently compressed and the lower half suddenly pulled apart, with almost no splintering. This piece had a small knot on the upper side, five inches from the center of the beam, but it appeared to have no effect upon the strength of the beam.

Piece No. 4 broke in a rather peculiar manner. While under a load of 575 lbs., the lower fibers for about a depth of one-tenth of an inch snapped apart, and the beam gradually settled down until the next layer of fibers had apparently the same deflection as did the lower ones at the time of breaking, when they also snapped, making a layer of about the same thickness. In this way the whole lower half of the beam seemed to divide

itself into layers of about one-tenth of an inch thick, and to break separately under about the same deflection, so that the beam was a long time in breaking.

Observing that under every load that had been applied the deflection kept increasing with the length of time the weight remained on the beam, piece No. 7 was subjected to a load of 275 lbs. for ninety-eight hours, during which time the deflection increased 0.079 inches. The weight was then taken off and the beam allowed to recover for twenty-four hours, when it had a set of .0446 inches. The same weight was again applied, and it was found that the deflection, obtained by taking the difference between the readings of the micrometer just before and after the weight was applied, was less than it was the first time the weight was applied, and the rate of increase of the deflection was about the same as before. The beam was thus subjected to a weight of 275 lbs. for three hundred hours in all, after which it was broken in the same manner as the others. It was expected that the effect of such a severe strain for so long a time would diminish its strength; but, on the contrary, it appeared to increase it, as the beam gave a higher Modulus of Rupture than any of the others, although it did not appear to be of as good quality as many of them. The ultimate deflection of this beam greatly exceeded that in any of the others.

Table III. shows the deflection of each beam under loads of 30, 40, 100, 400, 500, and 550 lbs., immediately after the load was applied, and at a distance of one inch from the center. The small figures under each deflection show what it would be if Hooke's Law held true, taking the deflection under 30 lbs. as the starting point.

TABLE III.

No. of Test Piece.	Deflection in inches under						Ultimate Deflection	Breaki'g weight: lbs.
	30 lbs.	40 lbs.	100 lbs.	400 lbs.	500 lbs.	550 lbs.		
1	0.0610	0.0826	0.2071	0.8303	1.0906	1.2791	1.5646	588
	.0610	.0813	.2030	.8120	1.0150	1.1165		
2	.0616	.0801	.2043	.8177	1.0677	1.2811	1.3941	575
	.0616	.0820	.2050	.8200	1.0250	1.1275		
3	.0606	.0815	.2023	.8976	1.2764	1.4800*	1.4800*	550
	.0606	.0808	.2020	.8080	1.0100	1.1110		
4	.0582	.0765	.1929	.7929	1.1146	1.3197	1.4658	575
	.0582	.0776	.1940	.7760	0.9700	1.0670		
5	.0580	.0774	.2004	.7876	1.0170	1.1827	1.5788	637
	.0580	.0773	.1933	.7732	0.9665	1.0631		
6	.0605	.0803	.2138	....	1.2520	1.4662	....	565
	.0605	.0806	.2016	....	1.0080	1.1088		
7	.0624	.0833	.2083	.8961	1.3595	....	....	550
	.0624	.0832	.2080	.8320	1.0400	....		
8	.0632	.0839	.2102	.8315	1.1111	1.3331	1.5709	585
	.0632	.0842	.2106	.8424	1.0530	1.1583		
9	.0619	.0823	.2063	....	1.0800	1.2830	1.4254	580
	.0619	.0825	.2063	....	1.0315	1.1346		
10	.0661	.0884	.2220	.9276	1.1772	1.3775	1.8100*	637
	.0661	.0881	.2203	.8812	1.1015	1.2116		

From these experiments I think we may draw the following conclusions:

That the Modulus of Elasticity depends not only upon the elasticity of the material, but also upon the length of time the load is applied.

That when subjected to loads not exceeding one-sixth of the breaking weight, spruce beams do not take a permanent set

That even under very small loads, if applied for any length of time, there will be a temporary set.

That knots and knarls in beams loaded at the center, when not within one-eighth of the span of the center of the beam, do not materially affect the elasticity under small loads.

That the deflection is very nearly proportional to the load, far beyond the customary limits of strain, and that the

*Approximately.

Modulus is consequently very nearly constant for all moderate deflections.

That a high Modulus of Elasticity does not always accompany high transverse strength; for, as shown by Table I., piece No. 10, which had the greatest transverse strength, gave next to the lowest value of E.

That in spruce beams the upper fibers commence to rupture by compression under about four-fifths of the breaking weight, and the neutral axis is very near the center of the beam as shown by the fracture.

That beams which are subjected to severe strains for a long time bend more before breaking than those which are broken in a comparatively short time.

That the Modulus of Elasticity of small spruce beams, of a quality such as is used in the best buildings, may be taken at from 1,600,000 to 1,700,000 lbs., and the Modulus of Rupture at about 11,000 lbs.

The only other experiments on American spruce with which the writer is familiar are those made by Mr. R. G. Hatfield on small beams, 1.6 feet between supports, and some experiments by Mr. Thomas Laslett, of England, on pieces of Canada spruce, 2 inches square and 72 inches between supports.

Mr. Hatfield gives as the average value of the transverse strength of a unit beam, 612 lbs..* which would give 11,016 lbs. for the Modulus of Rupture.

From data given by Laslett † we obtain as the value of R, 9,045 lbs.

The value generally given for the Modulus of Elasticity of spruce is 1,600,000 lbs.

GAS AND ELECTRICITY AS HEATING AGENTS.*

By Dr. C. WILLIAM SIEMENS, F.R.S.

From "Iron."

On the 14th of March, 1878, I had the honor of addressing you "On the Utilization of Heat and other Natural Forces." I then showed that the different forms of energy which Nature has provided for our uses had their origin, with the single exception of the tidal wave, in solar radiation; that the forces of wind and water, of heat and electricity, were attributable to this source, and that coal formed only a seeming and not a real exception to the rule—being the embodiment of a fractional portion of the solar energy of former geological ages.

On the present occasion I wish to confine myself to one branch only of the general subject, namely, the production of heat energy. I shall endeavor to prove that for all ordinary purposes of heating and melting gaseous fuel should be resorted to, but that for the attainment of extreme degrees of heat the electric arc possesses advantages, unrivaled by any other known source of heat.

Carbonaceous material such as coal or wood, is practically inert to oxygen at ordinary temperatures; but if wood is heated to 295° C. (593 Fah.), or coal to 326° C. (617° Fah.) according to experiments by M. Marbach, combination takes place between the fuel and the oxygen of the atmosphere, giving rise to the phenomenon of combustion. It is not necessary to raise the whole of the combustible materials to this temperature, in order to continue the action; the very act of combustion when once commenced gives rise to a great development of heat, more than sufficient to prepare additional carbonaceous matter, and additional air for entering into combination; thus a match suffices to ignite a shaving, and that in its turn to set fire to a building.

The first effect of combustion is, therefore to heat the combustible and the air necessary to sustain combustion to the temperature of ignition, but in dealing with the combustible called coal other preparatory work has to be accomplished, besides mere heating in order to sustain

* A lecture delivered before the Science Lecture Association, Glasgow.

* Hatfield's Transverse Strains, Table XLII.

† Timber and Timber Trees, Native and Foreign, by Thomas Laslett, Inspector to the Admiralty, London, 1875.

combustion. The following is an analysis from Dr. Percy's work on "Fuel" of a coal from the Newcastle district:

Carbon	81.41
Hydrogen	5.83
Oxygen	7.90
Nitrogen	2.05
Sulphur	0.74
Ash	2.07

which shows at a glance that nearly 16 per cent. of the total weight consists of such permanent gases as hydrogen, oxygen and nitrogen. Those gases are partly occluded or absorbed within the coal, but are also combined with carbon forming volatile compounds, such as the hydrocarbons and ammonia, so that when coal is subjected to heat in a closed retort, as much as 35 per cent. passes away from the retort in a gaseous condition and as vapor of water, partly to condense again in the form of tar, and of ammoniacal liquor, and partly to pass into the gas mains as illuminating gas, a mixture merely of marsh gas (CH_4), olefiant gas (C_2H_4), and acetylene (C_2H_2), its value as an illuminant depending upon the percentange of the last two constituents rich in carbon. The result of the distillation of a ton of coal will be as follows, from data with which Mr. A. Upward has kindly supplied me:

	Cwt.
Cake	13.60
Tar	1.20
Ammoniacal liquor	1.45
Gas	3.15
Carbonic acid	0.18
Sulphur removed by purifying	0.30
Loss	0.12

So great is the loss of heat sustained in an ordinary coal fire, in consequence of the internal work of volatilization, that such a fire is scarcely applicable for the production of intense degrees of heat, and it has been found necessary to deprive the coal in the first place of its volatile constituents (to convert it into coke) in order to make it suitable for the blast furnace, for steel melting, and for many other purposes where a clear intense heat is required.

In the ordinary coke oven the whole of the volatile constituents are lost, and each 100 lbs. of coal yield only 66 lbs. of coke, including the whole of the earthy constituents which on a large average may be taken at 6 lbs., leaving a balance 60 lbs. of solid carbon. In burning these 60 lbs. of pure carbon, 220 lbs. of carbonic anhydride (CO_2) are produced, and in this combination $60 \times 14{,}500 = 870{,}000$ heat units (according to accurate determinations by Favre and Silbermann, Dulong and Andrews) are produced.

The 34 per cent. of volatile matter driven off yield, when the condensible vapors of water, ammonia and tar, are separated, about 16 of pure combustible gas (being equal to about 10,000 cubic feet per ton of coal) which in combustion produce $16 \times 22{,}000 = 352{,}000$ heat units. The escape of these gases from the coke oven constitutes a very serious loss, which may be saved, to a great extent at least, if the decarburization is effected in retorts. The total heat producible from each 100 lbs. of coal is in that case $870{,}000 + 352{,}000 = 1{,}222{,}000$ or 12,220 units per lb. of coal. Deduction must, however, be made from this for the heat required to volatilize 34 lbs. of volatile matter for every 100 lbs. of coal used, and also for heating the coke to redness, or say to 1,000° Fah. Considering the multiplicity of gases and vapors produced it would be tedious to give the details of this calculation, the result of which would approximate to 60,000 heat units, or 600 units per lb. of coal treated.

We thus arrive at $12{,}200 - 600 = 11{,}600$ heat units as the maximum result to be obtained from 1 lb. of best coal. Considering, however, that the coal commonly used for industrial purposes contains more ashes and more water than has been here assumed, a reduction of say 10 per cent. is necessary, and the calorific power of ordinary coal may fairly be taken at 10,500 units per lb.

In applying this standard of efficiency to actual practice it will be found that the margin for improvement is large indeed. Thus, in our best steam-engine practice we obtain one actual horse-power with an expenditure of 2 lbs. of coal per hour (the best results on record being 1.5 lbs. of coal per indicated horse-power.) A horse-power represents $33{,}000 \times 60 = 1{,}980{,}000$ foot-lbs. per hour, which is $\frac{1{,}980{,}000}{2} = 980{,}000$ foot-lbs., or units of force, per lb. of fuel. Dr. Joule has shown us that 772 foot-lbs. represent one unit of heat, and 1 lb. of coal therefore produces $\frac{980{,}000}{772} = 1{,}282$ units

of heat, instead of 10,500, or only one-eighth part of the utmost possible result.

In melting steel in pots in the old-fashioned way, as still practiced largely at Sheffield, $2\frac{1}{2}$ tons of best Durham coke are consumed per ton of cast steel produced. The latent and sensible heat really absorbed in a pound of steel in the operation, does not exceed 1,800 units, whereas $2\frac{1}{2}$ lbs. of coke are capable of producing $13{,}050 \times 2.5 = 32{,}625$ units or 18 times the amount actually utilized.

In domestic economy the waste of fuel is also exceedingly great, but it is not easy to give precise figures representing the loss of effect, owing to the manifold purposes to be accomplished, including cooking and the heating and ventilation of apartments. If ventilation could be neglected close stoves, such as are used in Russia, would unquestionably furnish the most economical mode of heating our apartments; but health and comfort are, after all, of greater importance than economy, and these are best secured by means of an open chimney. Not only does the open chimney give rise to an active circulation of air through the room, which is a necessity for our well-being, but heat is supplied to the room by radiation from the incandescent material instead of by conduction from stove surfaces; in the one case the walls and furniture of the room absorb the luminous heat rays, and yield them back to the transparent air, whereas, in the latter case, the air is the first recipient of the stove heat, and the walls of the room remain comparatively cold and damp, giving rise to an unpleasant musty atmosphere, and to dry rot or other mouldy growth. The adversaries of the open fireplace say that it warms you on only one side, but this one-sided radiant heat produces upon the denizens of this somewhat humid country, and indeed upon all unprejudiced people, a particularly agreeable sensation; which is proof, I think, of its healthful influence. The hot radiant fire imitates, indeed, the sun in its effect upon man and matter, and before discarding it on the score of wastefulness and smokiness, we should try hard, I think, to cure it of its admitted imperfections.

If incandescent coke is the main source of radiant heat, why, it may be asked, do we not resort at once to coke for our domestic fuel? The reasons are twofold; the coke would be most difficult to light, and when lighted would look cheerless without the lively flickering flame.

The true solution consists, I venture to submit, in the combination of solid and gaseous fuel when brought thoroughly under control, by first separating these two constituents of coal. I am bold enough to go so far as to say that raw coal should not be used as fuel for any purpose whatsoever, and that the first step toward the judicious and economic production of heat is the gas retort or gas producer, in which coal is converted either entirely into gas, or into gas and coke, as is the case at our ordinary gas works.

When in the early part of the present winter London was visited by one of its densest fogs, many minds were directed towards finding a remedy for such a state of things. In my own case it has resulted in an arrangement which has met with a considerable amount of favor and practical success, and I do not hesitate to recommend it to you also for adoption. Its general application would, as regards dwelling houses, make our town atmosphere as clear as that of the surrounding country. If it can be shown that the arrangement may be easily and cheaply applied, that it will relieve our housemaids of the most irksome portion of their daily work in laying fires and cleaning grates, and that a warm and cheerful fire can be made at a considerably cheaper rate than when using coal, you will admit, I hope, that the proposal is worthy of a trial.

In outward appearance my fire-grate—which I have not made the subject of a patent, and which may, therefore, be put up by any grate or gas fitter without restraint—is very similar to the ordinary coal grate; the latter may, indeed, be converted into the smokeless grate at a very trifling cost. The essential features of this grate are, that solid carbonaceous fuel, such as coke or anthracite, are used in combination with as much gas as is found necessary to raise the former to the point of incandescence; that the combustion is entirely confined to the front of the grate, whence radiation into the room takes place; and that any heat

reaching the back of the grate is conducted away and utilized in heating the incoming air, by which combustion in front of grate is supported. In this way greater brilliancy and considerable economy are realized.

In one arrangement by which this is effected an iron dead plate is riveted to a stout copper plate facing the back of the fire grate, and extending 5 inches both upwards and downwards from the point of junction. The dead plate stops short about an inch behind the bottom bar of the grate to make room for a half-inch gas pipe, which is perforated with holes of about one-sixteenth of an inch placed at a distance of 1½ inches along the inner side of its upper surface. This pipe rests upon a lower plate, which is bent downwards towards the back, so as to provide a vertical and horizontal channel of about 1 inch in breadth between the two plates. A trap door, held up by a spring, is provided for the discharge of ashes falling into this channel. The vertical portion of this channel is occupied by a strip of sheet copper about 4 inches deep, bent in and out like a lady's frill, and riveted to the copper back piece.

Copper being an excellent conductor of heat, and this piece presenting (if not less than a quarter of an inch thick) a considerable sectional conductive area, transfers the heat from the back of the grate to the frill work in the vertical channel. An air current is set up by this heat, which, in passing along the horizontal channel, impinges on the line of gas flames, and greatly increases their brilliancy. So great is the heat imparted to the air by this simple arrangement, that a piece of lead of about half a pound in weight introduced through the trap door into this channel melted in five minutes—proving a temperature exceeding 619° Fah., or 326° C. The abstraction of heat from the back has, moreover, the advantage of retarding the combustion of the coke there while promoting it at the front of the grate.

I have used this arrangement in a fireplace at my office, in a room of 7,200 cubic feet capacity facing the north. I always found it difficult, during cold weather, to keep this room at 06° Fah. with a coal fire; but it has been easily maintained at that temperature since the grate has been altered to the gas-coke grate just described.

In order to test the question of economy, I have passed the gas consumed in the grate through a Parkinson's 10-light dry gas meter supplied to me by the Woolwich, Plumstead and Charlton Consumers' Gas Company. The coke used is also carefully weighed.

The result of one day's campaign of nine hours is a consumption of 62 cubic feet of gas and 22 lbs. of coke (the coke remaining in the grate being in each case put to the debit of the following day). Taking the gas at the average London price of 3*s.* 6*d.* per 1,000 cubic feet, and the coke at 18*s.* a ton, the account stands thus for nine hours:

62 cubic feet of gas at 3*s.* 6*d.* per thousand	2.604 *d.*
22 lbs. of coke at 18*s.* a ton	2.121
Total	4.725

or at the rate of 0.525*d.* per hour. In its former condition at a coal grate the consumption exceeded generally two and a-half large scuttles a day, weighing 19 lbs. each, or 47 lbs. of coal, which at 23*s.* a ton equals 5.7*d.* for nine hours, being 0,633*d.* per hour. This result shows that the coke-gas fire, as here described, is not only a warmer but a cheaper fire than its predecessor; with the advantages in its lit without the trouble of laying the fire, as it is called, and keep alight without requiring to be stirred, that it is thoroughly smokeless, and that the gas can be put off or on at any moment, which in most cases means considerable enonomy.

A second and more economical arrangement as regards first cost consists of two parts which are simply added to the existing grate, viz.: (1) the gas pipe with a single row of hole of about 1-16 inch diameter, 1.5 inch apart along the upper side inclining inward, and (2) an angular plate of cast iron, with projecting ribs extending from front to back on its under side, presenting a considerable surface, and serving the purpose of providing the heating surface produced by the copper plate and frill work in my first arrangement. In using iron instead of copper it is necessary, however, to increase the thickness of these plates and ribs in the inverse ratio of the conductivity of the two metals, or as regards

the back plate, from ¼ inch to ⅜ inch. An inclined plate, fastened to the lower grate bar, directs the incoming air upon the heating surfaces, and provides at the same time a support for the angular and ribbed plate which is simply dropped into its firm position between it and the back of the grate. The front edge of the horizontal plate has vandyked openings, forming a narrow grating, through which the small quantity of ashes, that will be produced by combustion of the coke or anthracite in the front part of the grate, discharge themselves down the incline towards the back of the hearth, where an open ash pan may be placed for their reception. In adapting the arrangement to existing grates, the ordinary grating may be retained to support the angular plate which has in that case its lower ribs cut short, to the level of the horizontal grate.

A considerable number of grates have now been constructed or altered in accordance with my plan, and have given great satisfaction to the users, on account of convenience and economy, which are conditions essentially necessary, if we are to make any way toward the more important, I may say national, result of a "smokeless London," a smokeless Manchester, and a smokeless Glasgow. But it may be asked, are you sure that the coke and gas grate you advocate, will do away with fogs and smoke? My answer is, that it would certainly do away with smoke, because the products of combustion passing away into the chimney are perfectly transparent. Mr. Aitken has, however, lately proved in an interesting paper read before the Royal Society of Edinburgh, that even with perfect combustion a microscopic dust is sent up into the atmosphere, each particle of which may form a molecule of fog. We have evidence, indeed, that the whole universe is filled with dust, and this is, according to Professor Tyndall, a fortunate circumstance, for without dust we should not have a blue but a pitch black sky, and on our earth we should be, according to Mr. Aitken, without rain, and should have to live in a perpetual vapor bath. The gas fires would contribute, it appears, to this invisible dust, and we should, no doubt, continue to have fogs, but these would be white fogs, which would not choke and blacken us.

Granted the cure of smoke, it might still be questioned whether such a plan as here proposed could be carried out, on so large a scale as to affect our atmosphere, with the existing mains and other plant of the gasworks. If gas were to be depended upon entirely for the production of the necessary heat, as is the case with an ordinary gas and asbestos grate, it could easily be proved that the existing gas mains would not go far to supply the demand; each grate would consume from 50 to 100 cubic feet an hour, representing in each house a consumption exceeding many times the supply to the gaslights. My experiments prove, however, that an average consumption of from 6 to 8 cubic feet of gas per hour suffices to work a coke-gas grate, on the plan here proposed. This is about the consumption of a large Argand burner, and therefore within the limits of ordinary supply. But, independently of the practical question of supply, it is desirable on the score of economy to rely upon the solid carbon chiefly for the production of radiant heat, for the following reason:

1,000 cubic feet of ordinary illuminating gas weigh 34 lbs., and the heat developed in their combustion amounts to $34 \times 22{,}000 = 748{,}000$ heat units.

One pound of solid coke develops in combustion, say, 13,400 heat units (assuming 8 per cent. of incombustible admixture) and it requires $\frac{748{,}000}{13{,}400} = 56$ lbs., or just half a hundred weight, of this coke to produce the same heating effect as 1,000 cubic feet of gas. But 1,000 cubic feet of gas cost on an average 3*s.* 6*d.*, and a half hundred weight of coke not more than 6d. (at 20*s.* a ton), or only one-seventh part of the price of gas.

If heating gas was supplied at a much cheaper rate it would, in many cases, be advantageous to substitute incombustible matter, such as balls of asbestos for the coke or anthracite. The consumption of gas would in that case have to be increased very considerably, but the economical principle involved (that of heating the air of combustion by conduction from the back of the grate) would still apply, and produce economical results as compared with those obtained by the gas-asbestos arrangements

hitherto used. To illustrate the efficiency of this mode of heating the incoming air by what is called waste heat, I will show you another application of the same principle which I have made very recently to the combustion of gas for illuminating purposes.

Gas engineers have been under the impression until now that a supply of cold air was favorable to the production of a brilliant flame. This is a misconception which was very general also as regards the combustion of solid fuel in furnaces, until it was disproved by Stirling, by Neilson, and by the introduction of the regenerative gas furnace. The "duplex burner" owes its brilliancy to the heating effect of the one burner upon the other; and my brother, Mr. Frederick Siemens, has more recently constructed a burner in which the flame of the gas is reversed in its action in order to heat in its descent the ascending current of flame-supporting air. By the application of the principle of conduction before described, I obtain the hot-air current in the most simple manner without interfering with the free action of the flame. In my arrangement an ordinary Argand burner takes its supply of gas through an enlarged vertical copper tube. This copper pipe terminates in a rod of highly conductive copper, which passes upward through the burner, and carries at its top a ball of porcelain or other refractory material. The rod is coated with platinum or nickel to prevent oxidation when heated (almost to redness) by the heat of the flame. The tube is armed with radial plates of copper presenting a considerable aggregate surface, and abutting externally against a covering of asbestos or other non-conductive material.

The waste heat of the flame, or that portion of the heat produced in combustion which is not utilized in luminous rays, serves to heat the ball of refractory material and the conductive rod. The heat is thus transferred by conduction to the upright copper tube, with its laminar radii, between the extensive surfaces of which currents of air are free to ascend towards the Argand burner. The air is thus heated to from 700° to 800° Fah. before meeting the gas, and the ultimate temperature of the flame is increased to at least the same amount, causing a larger proportion of the heat developed in combustion to reach the point of luminous radiation. But not only the quantity of light, but its quality, is improved by the higher temperature obtained. It may appear surprising, but it is a fact susceptible of accurate proof, that the light obtained in consumption of a given amount of gas may thus be increased by some 40 per cent., and that in this large proportion the deleterious influences connected with gas lighting may be diminished. Gas will thus be better able to hold its position against its more brilliant rival the electric light, except for such large applications as the lighting of public halls and places, of harbor, railway stations, warehouses, &c., for which it is pre-eminently suited. Add to these improved applications of gas the ever-increasing ones for heating purposes, and I have only to express regret that I am not a gas shareholder. If gas is to be largely employed, however, for heating purposes, it will have to come down in price; and considering that heating gas need not be highly purified, or possessed of high illuminating power, the time will come, I believe, when we shall have two services, one for illuminating and the other for heating gas.

In many towns two systems of gas mains already exist; and it would only be necessary to appropriate the one for illuminating and the other for heating gas. The ordinary retorts could be used for the production of both descriptions of gas, it being well known that even ordinary coal will give up gases of high illuminating power during a certain portion of the time occupied in their entire distillation. The gases emitted from the retort when first charged are to a great extent occluded gases of low illuminating power such as fire damp or marsh gas, and these should be turned into the heating mains. In the course of half an hour these occluded gases, together with the aqueous and other vapors will have left the coal, which is then in the best condition to evolve olefiant gas and other gases rich in carbon, and therefore of higher illuminating power. The period during which such illuminating gases are emitted extends over probably two hours, after which the retorts should again be connected with the heating gas mains, until the end of the process. The result

of this *modus operandi* would be that the illuminating gas supplied, say in London, from Newcastle coal, would probably exceed 20-candle power, instead of 16, as at present, whereby the objectionable results of gas lighting would be greatly diminished, and there would be, say, an equal volume of heating gas available, consisting for the most part of marsh gas, which, although greatly inferior to olefiant gas in illuminating effect, would be actually more suitable for heating purposes, because less liable to produce soot in its combustion.

The total cost of production would not be increased by this separation of the gases, and the price might, with advantage both to the supplier and to the consumer, be so adjusted that the latter, while paying for his illuminating gas an increased price proportionate to the increase of illuminating power, would be furnished with a heating gas at greatly reduced cost; for the heating gas would be reduced in price in a much larger proportion than the illuminating gas would have to be raised, because it would not require the same purification from sulphur which renders illuminating gas comparatively costly. The enormous increase of consumption would moreover enable the gas companies to reduce prices all round very considerably without interfering with their comfortable revenues.

For large applications of heating gas to the working of furnaces and boilers, simpler means than the retort can be found for its production. I constructed a gas producer many years ago in connection with my regenerative gas furnace, which I need not now describe in detail. In it all the carbonaceous matter of the coal is converted into combustible gas, the solid carbon yielding a supply of carbonic oxide; the resultant mixture of combustible gas contains a very large proportion, averaging 61.5 per cent., of nitrogen, which swells its volume without in any way contributing to its heating power. It has been my endeavor for some time to construct a gas producer which, without losing the simplicity of the first, should be capable of yielding a heating gas of superior calorific power. This producer consists of a wrought-cylindrical chamber, truncated downwards, and lined with brickwork. The fuel to be converted into gas is introduced through a hopper, and the cinder and ashes work out through the open orifice at the bottom.

Instead of a grating for the introduction of atmospheric air a current of heated air is brought in, either through the hopper or through the orifice at the bottom, and is discharged into the center of the mass of fuel; the effect is the generation of a very intense heat at that point. The fuel, after its descent through the hopper, arrives gradually at this region of intense heat, and when subjected to it, parts with its gaseous constituents. At the point of maximum heat coke is consumed, producing carbonic anhydride, which, in passing through the considerable thickness of fuel surrounding this portion, takes up a second equivalent of carbon and becomes changed into carbonic oxide. Here also the earthy constituents are for the most part separated in a fused or semi-fused condition, and in descending gradually reach the orifice at the bottom, whence they are removed from time to time. Air enters through the bottom orifice to some extent, causing the entire consumption of the carbonaceous matter, which may have got past the zone of greatest heat; water is also here introduced in a hollow tray, and after evaporation by the heat of the hot clinkers, passes upwards through the incandescent mass, and is converted by decomposition into carbonic oxide and hydrogen gas. The exit orifices for the gases are placed all round, near the circumference of the chamber, ascending upwards into an annular space, whence they are taken through pipes to the furnace or other destination. The advantages connected with this *modus operandi* consists in the intensity of the heat produced within the center of the mass, whereby the whole of the fuel is converted into combustible gases, with the least amount of nitrogen. The hydrocarbons formed in the upper portion of the apparatus have to descend through the hotter fuel below, and in so doing, the tar and other vapors mixed up with them are decomposed, and furnish combustible gases of a permanent character.

The orifice at the bottom of the apparatus may be enlarged and so arranged that, instead of ashes only being produced, coke may be withdrawn, and in

this way a continuous coke oven may be constructed, which is at the same time a gas producer, or, in other words, an apparatus in which both the solid and gaseous constituents of the coal are fully utilized. The intense heat in the very center of a large mass of fuel has for its result a very rapid distillation, and thus one gas producer does the work of two or three gas producers of the type hitherto employed; this more concentrated action will moreover allow of the introduction of gaseous fuel, where want of space and considerations of economy have militated hitherto against it, and in favor of the ordinary coal furnace. It has been already proved that steam boilers can be worked economically on land with gaseous fuel, and there is no reason that I know of why the same mode of working should not also be applied to marine boilers. The marine engine has within the last fifteen years been improved to an extent which is truly surprising; the consumption of coal, which at the commencement of that period was never less than 8 lbs. per horse power, has been reduced by expansive working in compound cylinders to 2 lbs. or even less per actual horse-power. The mode of firing marine boilers has, however, remained the same as it was in the days of Watt and Fulton. In crossing the Atlantic one may see a considerable number of men incessantly employed in the close stoke hole of the vessel opening the fire doors and throwing in fuel. Each charge gives rise to the development of great clouds of black smoke issuing from the chimney, to the great annoyance and discomfort of the passengers on deck. If, instead of this, the fuel could be discharged mechanically into one or more gas producers, the gaseous fuel produced would maintain the boilers at a very uniform heat, without necessitating the almost superhuman toil of the firemen; no smoke or dust would be emitted from the chimney, and a large saving of fuel would be effected.

This change would be specially appreciated by the numerous tourists visiting the Western Highlands. Speaking from my own experience on one occasion, I may say that the pleasure of a trip on the beautiful Loch Lomond was very seriously marred in consequence of the fumigation which my fellow-passengers and myself had to endure. The change from the use of solid to gaseous fuel would be the prelude probably to another, and still more important change, namely, the entire suppression of the steam boiler. We are already in possession of gas engines working at moderate expense as compared with small steam engines, even when supplied with the comparatively expensive gas from our town gas mains, and all that will be required is an extension of the principle of operation already established. The realization of such a plan would, of course, involve many important considerations, and may be looked upon as one of those subjects the accomplishment of which may be left for the energy and inventive power of the rising generation of engineers.

Before leaving this branch of the subject, I wish to call attention to a favorite suggestion which I had occasion to make some years ago. It consists in placing gas producers at the bottom of the coal mines themselves, so that instead of having to raise the coal by mechanical power, the combustible gases ascending from the depth of the mine to the surface would acquire by virtue of their low specific gravity such an onward pressure that they could be conducted in tubes to distances of many miles, thus saving the cost of raising and transporting the solid fuel. Glasgow, with its adjoining coal fields, appears to me a particularly favorable locality for putting such a plan to a practical trial, and the well-known enterprise of its inhabitants makes me sanguine of its accomplishment. When thus supplied with gaseous fuel, the town would not only be able to boast of a clear atmosphere, but the streets would be relieved of the most objectionable portion of the daily traffic.

I now approach another and the last portion of my address, the attainment of very intense degrees of heat either for effecting fusion or chemical decomposition. Although by means of the combustion of either solid or gaseous fuel heats are produced which suffice for all ordinary purposes, there is a limit imposed upon the degree of temperature attainable by any furnace depending upon combustion. It has been shown by Bunsen and by St. Claire Deville, that at certain temperatures the

chemical affinity between oxygen on the one hand and carbon and hydrogen on the other absolutely ceases, and that if the products of combustion CO_2 and H_2O be exposed to such a degree of temperature they would fall to pieces into their constituent elements. This point of dissociation, as it is called, is influenced by pressure, but has been found for CO_2 under atmospheric pressure to be 2600° C, (or 4700° Fahr.). But long before this extreme point has been arrived at, combustion is greatly retarded, and the limit is reached when the losses of heat by radiation from the furnace balance its production by combustion. To electricity we must look for the attainment of a temperature above that of dissociation, and we have evidence of the early application of the electric arc to such a purpose. In 1807 Sir Humphrey Davy succeeded in decomposing potash by means of an electric current from a Wollaston battery of 400 elements, and in 1810 he surprised the members of the Royal Institution by the brilliant electric arc produced between carbon points through the same agency. Magneto-electric and dynamo-electric currents allow of the production of the electric arc much more readily and economically than by the use of Sir Humphrey Davy's gigantic battery, and Messrs. Huggins, Lockyer and Liveing, and other physicists, have taken advantage of the comparatively new method to advance astronomical and chemical research with the aid of spectrum analysis.

My object is now to show that the heat of the electric arc is not only available within a focus, or extremely contracted space, but that it is capable of producing such larger effects as will render it useful in the arts for fusing platinum, iridium, steel, or iron, or for effecting such reactions or decompositions as require for their accomplishment an intense degree of heat, coupled with freedom from such disturbing influences as are inseparable from a furnace worked by the combustion of carbonaceous material. The apparatus which I employ to effect the electro-fusion of such material as iron or platinum consists of an ordinary crucible of plumbago, or other highly-refractory material, placed in a metallic jacket or outer casing, the intervening space being filled up with pounded charcoal or other bad conductor of heat. A hole is pierced through the bottom of the crucible for the admission of a rod of iron, platinum, or dense carbon, such as is used in electric illumination. The cover of the crucible is also pierced for the reception of the negative electrode, by preference a cylinder of compressed carbon of comparatively large dimensions. At one end of a beam supported at its center is suspended the negative electrode by means of a strip of copper, or other good conductor of electricity, the other end of the beam being attached to a hollow cylinder of soft iron free to move vertically within a solenoid coil of wire, presenting a total resistance of about 50 units or ohms. By means of a sliding weight the preponderence of the beam in the direction of the solenoid can be varied so as to balance the magnetic force with which the hollow iron cylinder is drawn into the coil. One end of the solenoid coil is connected with the positive, and the other with the negative pole of the electric arc, and, being a coil of high resistance, its attractive force on the iron cylinder is proportional to the electro-motive force between the two electrodes, or, in other words, to the electrical resistance of the arc itself.

The resistance of the arc was determined and fixed at will within the limits of the source of power, by sliding the weight upon the beam. If the resistance of the arc should increase from any cause, the current passing through the solenoid would gain in strength, and the magnetic force overcoming the counteracting weight, would cause the negative electrode to descend deeper into the crucible; whereas, if the resistance of the arc should fall below the desired limit, the weight would drive back the iron cylinder within the coils, and the length of the arc would increase, until the balance between the forces engaged had been re-established. Experiments with long solenoid coils have shown that the attractive force exerted upon the iron cylinder is subject only to slight variation within a range of several inches, which circumstance allows of a working range to that extent of nearly uniform action on the electric arc.

This automatic adjustment of the arc is of great importance to the attainment

of advantageous results in the process of electric fusion; without it the resistance of the arc would rapidly diminish with increase of temperature of the heated atmosphere within the crucible, and heat would be developed in the dynamo-electric machine to the prejudice of the electric furnace. The sudden sinking or change in electrical resistance of the material undergoing fusion would, on the other hand, cause sudden increase in the resistance of the arc, with a likelihood of its extinction, if such self-adjusting action did not take place.

Another important element of success in electric fusion consists in constituting the material to be fused the positive pole of the electric arc. It is well known that it is at the positive pole, that the heat is principally developed, and fusion of the material constituting the positive pole takes place even before the crucible itself is heated up to the same degree. This principal of action is of course applicable only to the melting of metals and other electrical conductors, such as metallic oxides, which constitute the materials generally operated upon in metallurgical processes. In operating upon non-conductive earth or upon streams of gases, it becomes necessary to provide a non-destructible positive pole, such as is supplied by the use of a pool of fused platinum, or iridium, or by a plumbago crucible. In working the electric furnace, some time is taken up in the first instance in raising the temperature of the crucible to a considerable degree, but it is surprising how rapidly an accumulation of heat takes place. In using a pair of dynamo-machines capable of producing seventy webers of current with an expenditure of 7 horse-power, and which, when used for purposes of illumination, produce a light of 12,000 candles, a crucible of about 8 inches in depth, immersed in a non-conductive material, has its temperature raised to a white heat in fifteen minutes, and 4 lbs. of steel are fused within another fifteen minutes, successive fusions being effected in somewhat diminishing intervals of time. The process can be carried on on a still larger scale by increasing the power of the dynamo-machines and the size of the crucibles.

The purely chemical reaction intended to be carried into effect within the crucible might be interfered with through the detachment of particles from the dense carbon used for the negative pole, although its consumption within a neutral atmosphere is exceedingly slow. To prevent this I have used, both in this connection and also in the construction of electric lamps, a water pole, or tube of copper, through which a current of water circulates, so that it yields no substance to the arc. It consists simply of a stout copper cylinder closed at the lower end, having an inner tube penetrating to near the bottom for the passage of a current of water into the cylinder, which water enters and is discharged by means of flexible india-rubber tubing. This tubing being of non-conductive material, and its sectional area small, the escape of current from the pole to the reservoir is so slight that it may be neglected. On the other hand, some loss of heat is incurred through conduction, with the use of the water pole, but this loss diminishes with the increasing heat of the furnace, inasmuch as the arc becomes longer, and the pole is retired more and more into the crucible cover.

In the experiments which I shall now place before you the current which has supplied the one electric lamp in the center of the hall will be diverted by means of a commutator through the electric furnace. After it has been active for five minutes to warm the crucible, I shall charge it with 8 lbs.of broken steel files, which I shall endeavor to melt and pour out into an ingot mould before your eyes. By some obvious modifications of this electric furnace, it can be made available for a variety of other purposes where intense heat is required, combined with immunity from disturbing chemical actions. By piercing a number of radial holes through the sides of the chamber, and introducing the ends of wires through the same, an excellent means is provided of heating those wire ends very rapidly, without burning them, for the purpose of welding them together. The electrical furnace will also be found useful, I believe, in the hands of the chemist, to effect those high temperature reactions between gaseous bodies which require the employment of temperatures far exceeding the hitherto available limits, and will thus increase the area of available reactions at his dis-

posal for the attainment of either scientific or practical ends.

I have endeavored to compress within the limited space of a single lecture subject matter that might occupy the close attention of the student for weeks or months; and I may, therefore, be pardoned if I have failed to convey to you more than a very rough outline of what may be accomplished by the judicious use of gaseous fuel, and of the electric current, as heating agents. The one purpose that has been foremost in my mind in preparing this lecture has been to make war upon the smoky chimney—which, so far from being a necessity under any circumstances whatever, should be regarded only as a remnant of that stage of our industrial and social progress which, satisfied with the attainment of certain ends could afford to neglect the economical and sanitary conditions under which those ends were accomplished. The exhibition, which has lately been held in this city, of appliances for heating and illuminating by means of gas and electricity, in which your President, my esteemed friend, Sir William Thomson, took so prominent a part—as he does in everything tending towards the advancement of human knowledge and well being—proves how deep is the interest felt amongst you in those very questions with which I have had to deal this evening. And so I thought you might not be disinclined to give attention once more to a particular view of the question, which happens to be the result of the independent labor of one who may claim, at any rate, to have given a life-long attention to the subject.

THE EFFECT OF PUNCHING ON STEEL AND IRON PLATES.

From "The Engineer."

We referred recently to certain experiments made by the Board of Trade on steel plates for boilers and ships. The most prominent feature in Mr. Trail's report is the absence of information on those points which most perplex engineers and shipbuilders; and before we have done we hope to make this fact very clear, in the hope that others will take new ground, and quit the beaten path of experiment, which, it may now be safely said, cannot lead us to a knowledge of that which we wish to know. It will be remembered that all the plates tested were pulled asunder by Mr. Kirkaldy, and the results obtained, although in many respects new to many persons, are just what were anticipated by those who have made steel a special subject of study. But, although this is true of most of the results obtained it is not true of all; and some of them are opposed in a small degree to those obtained by other inquirers. It is of the utmost importance that the effect produced on a plate by making holes in it should be understood very plainly. There are four ways in which a rivet hole may be made. It can be punched, or it can be drilled, or it can be punched first and drilled subsequently, or it can be first drilled, and then punched. The value of all the three first-named systems has been repeatedly tested, but no one has tested the fourth, and yet it appears to have much to recommend it. It is well known that when a plate is punched the hole is always a little conical, and this conical shape is of much value, because it relieves the rivet head or point to some extent of strain, and even though the head should fly off the rivet is still useful. Drilled holes are not conical, and this is admitted to be a serious objection to them, and besides they are expensive. Now, if plates requiring such holes were first drilled to, say, $\frac{3}{4}$ in., and then punched up to the proper dimensions, say 1 in., the cost of drilling would be reduced, and the conical punched hole would be obtained. It remains to be seen whether under such conditions the plate would or would not be weakened by the punching; as on this point we possess no information we must content ourselves with suggesting to any one about to test steel the advisability of trying what would be found a very simple experiment. As regards the other three systems, the Board of Trade

carried out, as we have said, a number of experiments with results the general nature of which we have already indicated. They appear to show that when a plate is punched it loses strength, but that when punched and annealed, or punched and rimed out to size, or drilled, it gains in strength. Thus a ¼ in. plate which, unperforated, bore a strain of 30.7 tons per inch, bore 31.6 tons when punched and annealed, 31.23 tons when punched small and bored to size, and 31.46 tons when drilled. With a 1 in. plate the figures are 28.17 tons for the solid plate, punched 21.26, punched and annealed 29.12, punched small and bored to size 29.15, and drilled 28.43 tons; all the dies were about 20 per cent. larger in diameter than the punch. Putting these figures into percentages we have for the ¼ in. plate—the strength of the solid plate being 100—punched 93.8, punched and annealed 104.7, punched small and bored out 103.5, drilled 104.2; for the 1 in. plate the figures are 75.4, 103.3, 103.4, and 100.9. Here, again, we have ample corroboration of our often urged argument that the properties of thin steel plates do not form a guide to those of thick steel plates.

If we compare these results with others obtained at different times, and by other experimenters, it will be seen that some difference exists. Thus experiments made at Liverpool and Sheffield in 1878 showed that ¼ in. plates lost only about 8 per cent. by punching, which nearly agrees with the figures given above, while the 1 in. plates lose more than 33 per cent., instead of less than one-fouth, as given above. Again, according to the Board of Trade, steel plates ½ in. thick lost but 8.6 per cent. by punching, while in the experiments of which we speak the loss was found to reach as much as 26 per cent. We have here a very important disparity, and one which should be cleared up. Is it to be explained by differences in the quality of the steel, or by peculiarities in the system of testing employed? So far as we can see it depends entirely on the first condition, namely, the quality of the steel; and it should be remembered that in both cases the steels used were ostensibly the best that could be made. We find then that while the steel made by one firm will lose less than 9 per cent. by being punched, the steel made by another firm, at least as eminent, loses 26 per cent., or nearly three times as much. Furthermore, it is stated that the effect of punching is to deprive the metal of all power of stretching, and the consequence is that it breaks with a crystalline instead of with a fine silky fracture. Bearing these facts in mind, let us consider what light they throw on the peculiarities of steel. It is known that if a steel boiler plate be punched, the chances are about one hundred to one that cracks will start from all the rivet holes in the edges of the plate, if not from one to the other, almost before the riveting of the seam is completed. On the other hand, Lloyds permit steel ship plates to be punched and riveted up without riming or annealing, provided they are not more than ½ in. thick, and do not come under severe strains—garboard strakes, sheer strakes, and deck stringer plates must, if punched, be annealed or rimed. Leaving ships, however, and returning to boilers, we may say at once that no one dreams of putting a steel boiler together with punched holes, unless the plates are carefully annealed. On the other hand, scores of iron boilers are made with punched holes, and no cracking takes place, and the boilers are quite sound and good. To this it will be replied that iron does not lose strength by being punched, and that for that reason it may be punched with safety. It will, perhaps, be new to many of our readers, but it is none the less true, that this is a complete mistake. Iron boiler plates do lose in strength by punching. A set of experiments made in 1878 on best boiler plates ¾ in. thick, such as are used for marine boilers of moderate size, showed that while the solid plate had a tensile strength of very nearly 20 tons per square inch, the metal lost in strength when punched with an open die, 22 per cent.; when punched with a close die, 20 per cent.; when punched and rimed, 11.4 per cent.; and when punched and annealed, 4 per cent. of its original strength. A second set of experiments on ostensibly a better class of "best best" plates as supplied to the Admiralty showed that under similar conditions the iron lost 18 per cent. of its strength by punching, and even when

the holes were rimed the loss was 9.2 per cent., and when they were drilled 3 per cent. Here we see that although the loss is somewhat less than is the case with steel, it is nevertheless very considerable. But the injury inflicted on iron by punching does not seem to become apparent. The metal keeps its sorrows to itself. It shows no outward signs, and the 80 per cent. or so of strength left in the plate is always worth 80 per cent. But of the 80 per cent. or so left in steel no one can tell the value even approximately. Why is this? All the explanations which have been put forward to supply an answer will apply just as strongly to iron.

We are told that when a steel plate is punched, a ring of hard metal is left round the hole, which being compressed tends to split the plate, or prevents the strains being equally distributed through it.

Remove this hard ring with the rimer, or soften it by annealing, and the plate becomes as strong as ever. But does not all this hold good of punched iron? Is there not in its case a hard ring round the holes? Cannot this ring be rimed with the rimer or softened away by fire? The answer must be in the affirmative. The only feature indicating a different condition is that iron seems to be permanently injured to a small extent even by drilling, while steel is improved. The hard rings will not render an iron plate treacherous, while they make steel plates quite untrustworthy. Like causes, in a word, do not produce like effects; and to complicate the case still further, a Motala plate from Sweden, did not seem to lose any strength by being punched, plates .45 in. thick having an initial strength varying between 27 and 28 tons per inch before punching, and standing as much as 28.2 tons after punching.

We have little reason, then, to doubt that the true reason why punched steel plates will not answer for constructive purposes, while iron plates will answer, has yet to be sought out, and the inquiry must take two distinct directions. In the first place, we must have much more accurate analyses of steel to deal with than are now available, and chemists appear to be agreed that to make them they must operate on comparatively large quantities of the metal. It is very easy to speak, for instance, of .1 per cent. of carbon, but few persons realize what it is the chemist who seeks for this has to find. 0.1 per cent. of carbon means that a ton of steel contains 2.24 lbs. of carbon, each pound of the metal will contain 7 grains of carbon; and as the chemist operates on but a few grammes of the steel at a time, it will be seen how minute are the quantities of carbon, sulphur, and phosphorus with which he has to deal. But this would present no difficulty were it not that the analysis of iron, especially for carbon, is one of the most troublesome known, and we feel certain that many statements which now serve to perplex investigators struggling to arrive at the truth would be found erroneous if only accurate analyses were available. Again, the testing of steel plates in a machine is not a true test, because it specially eliminates the conditions under which steel suffers most, and is least trustworthy. Thus the strength of riveted steel joints should be ascertained by putting sudden strains on them, such as they may be supposed to suffer when a long ship is steaming head to wind in a heavy sea; and again, tests of boiler plates ought to be made with the plates hot, not cold. The inquiries which have been made up to the present are so misleading, that little or no regard is paid to them; and those who use steel freely rely entirely on their own practical acquaintance with it, and care little or nothing for the figures which exist in such multitudes. The great safeguard seems to be to deal for steel only with firms who have already supplied what has proved to be good. This is very hard, perhaps, on young firms; but it is not easy to see how it can be helped. If only steel did not now and then play those who use it false; if only it were not so susceptible of being deteriorated, that a change in the form of the ingot moulds has been known alone to suffice to render tons of steel next to useless, iron would cease to be made save for a few special purposes. The unsatisfactory aspect of the steel question as a whole is that we seem to make no progress, and that we know no more about it now than we did five years ago.

THE OPTICAL DYNAMOMETER.

Translated from "l'Electricien."

In testing dynamo-electric machines it is a matter of considerable importance to determine the amount of work absorbed by the machine alone, without the intervention of other factors which are capable of affecting to an important extent the value of this work.

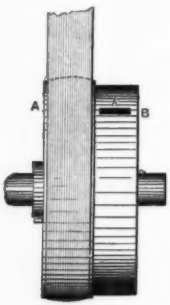


Fig.1

To measure the work with accuracy it is necessary to determine the tangential effort and the velocity at the point of application. The velocity is easily obtained by measuring the radius and counting the revolutions of the machine. The only difficulty is in measuring the tangential effort

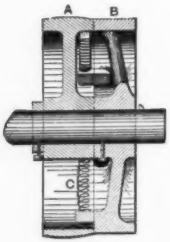


Fig.2

Different devices have been employed for this purpose. In some the difference in tension between the belt leading to the driving pulley and the belt leading from it has been measured. In others the effort of the driving pulley to turn the shaft has been measured by a spiral spring.

The dynamometer of M. Satchinoff presents the peculiarity of permitting the reading to be taken directly while the machine is in motion. The reading is made from graduations on the inner surface of a moving pulley, and is based on the principle of persistence of luminous impressions on the retina.

The figures 1 to 4 exhibit the plan of working of the apparatus. It consists of two pulleys, A and B, the former running loose upon the driving shaft, while B is keyed fast to it. The arms of the pulley A are attached to those of B by three spiral springs C, C, C. B is furthermore

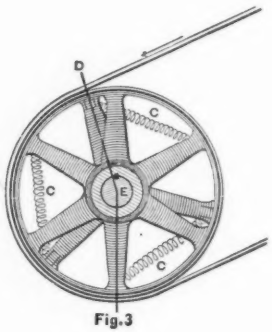


Fig.3

furnished with a rectangular slit R, through which the readings are made while the machine is in motion.

Under ordinary circumstances the driving belt is run on the keyed pulley B, and the shaft is then driven without any strain on the dynamometer. When a test of the power is required, the belt is run upon the pulley A, as shown in Fig. 4. The shaft is then driven through the agency of the springs, and there results a certain amount of angular displacement of the pulleys, the amount of which depends upon the effort required to overcome the resistance to be measured. The graduations on the inner surface of the pulley A serve to measure the displacement, and consequently the

strain, by referring to the fixed reference point *n* on the edge of the pulley B.

The slit R is placed opposite to *n*, and may be read directly in pounds or kilograms.

This dynamometer is very simple, and

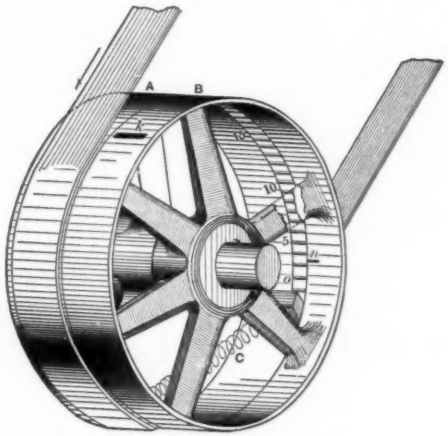


Fig.4

permits *n* and the graduations to be plainly seen while the wheels are in rapid motion. By previous adjustment of the springs the force or resistance capable of a great variety of applications, and it is especially serviceable in cases of high velocity, a condition met with in all the dynamo-electric machines.

WEIGHT, SPECIFIC GRAVITY, RATES OF ABSORPTION AND CAPABILITIES OF STANDING HEAT OF VARIOUS BUILDING STONES.

By HIRAM A. CUTTING, Ph. D., State Geologist Vermont.

HAVING during the past year instituted, and carried out, a series of experiments to ascertain, as nearly as possible, the capabilities of the various materials used in the construction of so-called fireproof buildings to stand heat, I submit, in tabulated form, the result of such experiments, hoping they may be of use to the architects, quarrymen and Insurance companies of our country, and also of some interest to those interested in science.

In connection with the capabilities of the various building stones to stand fire and water, I have taken their specific gravity, and weight per cubic foot, so that the identity of the various stones could at any time be compared, and if in the working of a quarry there was a change in gravity, or weight, that it could be easily detected, and thus all who choose could know whether the tests given would apply or not.

I have procured sample specimens of the most important building stones in the United States and Canada, and, after dressing them into as regular form as possible, three by four inches, and two inches in thickness, I have taken their ratio of absorption, which ratio I have expressed in units of weight, according to the amount of water taken up. If 450 units of stone absorbed one unit of water, I have expressed it thus: 1 + 450, mean-

ing that the stone weighed 450 units when immersed, and 451 when taken from the water.

To accelerate the process of absorption I have placed the specimens in water under the exhausted receiver of an air pump.

I find that in this way as much water is absorbed in a few minutes as in days of soaking. When specimens were removed from the water, I have, before weighing, dried their outsides with blotting paper. In relation to the specific gravity, I have not followed "Gilmore's" rule in full. He weighed the specimens in air, immersed them in water, and allowed them to remain until bubbling had ceased and then weighed them in water, after which he took them from the water, dried them outside with bibulous paper, and weighed them again in air. From this last weight he subtracted the weight in water, dividing the dry weight by the difference.

This gave a specific gravity subject to two sources of error. I have followed the more frequent custom of weighing the dry stone, using pieces of two or three pounds in weight, and then immersing them in water. After the usual saturation I have taken their weight in water, subtracting it from the dry weight in air, and then dividing the dry weight by the difference. This gives the specific gravity of the rock itself, as usually found, which is what we desire, and I believe as it would generally be in buildings constructed of the given material. The specimens were previously dried by long exposure to a temperature not exceeding 200° Fah. To verify this I have taken specimens from the quarries direct, and after weighing, have brushed them over with paraffine dissolved in naphtha, weighing them again so as to ascertain the exact amount of paraffine, which made no visible change in the stone, other than to keep out water. I have then weighed in the usual way, and thus obtained the exact specific gravity of the stone as in the quarry, and I find my method used, as stated, to give the best results, and so have adopted it.

After this I have placed them in a charcoal furnace, the heat of which was shown by a standard pyrometer. In many instances I have placed them side by side with dry specimens, but have been unable to note any marked difference in the action of heat, beyond this, that the dry specimens became sooner heated. I have, however, no doubt that the capacity of a stone to absorb water is against its durability, even in warm climates, and vastly more so in the changeable and wintry climate of New England. It is here often frozen before any considerable part of the moisture from Autumn rains can be evaporated.

When the specimens were heated to 600° Fah., I have immersed them in water, also immersing others, or the same, if uninjured, at 800° and 900°, that is if they are not spoiled at less temperatures. I find that all of these samples of building stones have stood heat without damage up to 500°. At 600° a few are injured; but the injury in many cases commences at or near that point. When cooled without immersion they appear to the eye to be injured less, but are ready to crumble, and I think they are many times nearly as much impaired, and always somewhat injured, when water produces any injury.

I would remark that my experiments with granites show that there is quite a range in their capabilities of standing heat, a range in fact much greater than I anticipated. With the sandstones the difference is also marked, as is their power of absorption. When exposed to the heat wet, they show a marked difference in the time required to heat them, the saturated ones seeming to resist the heat for a time; but when equally hot they crumble the same as those not previously saturated. Their relative worth can be seen by the table. The conglomerates stand heat badly; while the limestones and marble stand best of all (up to the point where they, by continued heat, are changed to quick lime) except soapstone, and a species of artificial stone made under the McMurtire & Chamberlain patent. The indications are, from this and other samples of artificial stone, that it may be possible to make an artificial stone cheaper and better for fireproof buildings than our native quarries furnish; and we hope this possibility may receive attention. But comments are useless, as the facts set forth in the tables speak for themselves.

I give you results in tabulated form on following pages:

GRANITES.

No.	Kind.	Locality.	Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	First appearance of injury.	Crumbles or cracks, slightly.	Cracks, badly, or becomes friable.	Injured so as to be worthless for a building.	Melted or ruined.
				lbs.		Deg. Fah.	Deg. Fah.	Deg. Fah.	Deg, Fah.	Deg. Fah.
1	Light colored	Hallowell, Me	2.638	164.8	1+790	800	900	950	1000	1100
2	"	Fox Island, Me	2.642	165.1	1+680	700	800	850	900	1000
3	Denning's Quarry	Mt. Desert, Me	2.631	164.1	1+716	800	850	950	1000	1100
4	Light colored	Rockford, Me	2.600	162.5	1+482	600	800	850	900	950
5	Red	Red Beach, Calais, Me	2.636	164.7	1+560	800	850	900	950	1000
6	Light colored	Oak Hill, Me	2.526	157.8	1+310	800	850	900	950	1000
7	Red	Stark, N. H	2.631	164.1	1+534	600	700	800	850	950
8	Colored medium	Concord, N. H	2.636	164.7	1+778	800	900	950	1000	1200
9	Sanborn's Quarry	Plymouth, N. H	2.649	165.5	1+685	800	900	950	1000	1200
10	Carter's Quarry	Ryegate, Vt	2.647	165.4	1+790	800	900	950	1000	1200
11	"	Woodbury, Vt	2.654	165.8	1+784	800	900	950	1000	1200
12	Wetmore & Morse's Quarry	Barre, Vt	2.651	165.6	1+720	800	900	950	1000	1200
13	Syenite	Quincy, Mass	2.660	166.2	1+650	750	800	850	900	1000
14	Gray	Croton, Conn	2.800	175.0	1+818	700	750	800	900	900
15	Common	Woodstock, Md	2.648	165.5	1+394	700	750	800	900	900
16	"	Port Deposit, Md	2.700	168.7	1+816	800	900	950	1000	1100
17	Scranton County Quarry	Richmond, Va	2.727	170.5	1+398	750	800	850	900	1000
18	Old Dominion Quarry	" "	2.674	167.7	1+402	750	800	850	900	1000
19	Light colored	St. Cloud, Minn	2.690	168.2	1+280	700	700	800	850	900
20	"	Stanstead, P. Q	2.833	177.0	1+420	800	900	1000	1000	1200
21	Coarse	North Halifax, N. S	2.698	168.6	1+584	700	800	800	900	900
22	"	Gananoque, P. O., Can	2.687	167.9	1+736	800	850	900	950	1000

LIMESTONE.

1	Limestone	Baltimore, Md	2.917	181.8	1+340	900	1000	1100	1200	1200
2	"	Bedford, Ind	2.478	154.8	1+280	850	900	1000	1200	1200
3	Cincinnati Limestone	Hamilton County, O	2.204	137.7	1+ 28	850	900	950	1200	1200
4	Potts Blue	Springfield, Penn	2.666	166.6	1+280	850	850	900	1000	1200
5	Dolomite Limestone	Owen Sound P. O	2.571	160.6	1+480	850	900	1100	1200	1200
6	Trenton Limestone	Montreal, P. Q	2.706	169.1	1+316	900	950	1000	1200	1200
7	Limestone	Isle La Motte, Vt	2.696	168.5	1+320	950	1000	1100	1200	1200

SANDSTONE.

No.	Kind.	Locality.	Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	First appearance of injury.	Crumbles or cracks, slightly.	Cracks, badly, or becomes friable.	Injured so as to be worthless for a building.	Melted or ruined.
						Deg. Fah.	Deg. Fah.	Deg. Fah.	Deg. Fah	Deg. Fah.
1	Freestone	Portland, Conn	2.380	148.7	1+ 27	850	900	950	1000	1100
2	"	North of England	2.168	135.5	1+ 27	850	900	950	950	1000
3	Seneca Stone	Montgomery Co., Md	2.500	156.2	1+ 26	850	900	900	950	950
4	Sandstone	Salem, Md	2.452	153.2	1+ 24	850	900	950	1000	1100
5	"	Seneca, Md	2.410	150.6	1+ 40	900	1000	1100	1200	1200
6	Montrose Stone	Ulster Co., N. Y	2.661	166.3	1+314	900	1000	1100	1200	1200
7	Freestone	Belleville, N. J	2.350	146.8	1+ 27	900	950	1000	1100	1100
8	"	Nova Scotia	2.424	151.5	1+240	900	950	1000	1100	1100
9	S. Carboniferous	Br. Phillipe, N. S	2.353	147.0	1+ 19	900	950	950	1000	1000
10	Freestone	Dorchester, N. B	2.363	147.7	1+ 26	800	850	900	1000	1000
11	Cincinnati Stone	Cincinnati, O	2.188	136.1	1+ 23	900	950	1000	1100	1100
12	Potsdam Sandstone	McBride's Corners, O	2.333	145.8	1+ 28	800	850	900	1000	1100
13	Berlin Stone	Cleveland, O	2.210	138.1	1+ 22	850	900	1000	1100	1100
14	Potsdam	McBride's Corners, O	2.500	156.2	1+ 22	850	900	950	1000	1000
15	Euclid Stone	Near Cleveland, O	2.290	143.1	1+ 35	850	900	950	1000	1000
16	Berea Stone	Berea, O	2.254	140.8	1+ 20	850	900	950	1000	1000
17	Amherst Stone	Amherst, O	2.200	137.5	1+ 18	850	900	changes color.		1000
18	Brown Stone	Humbletown, Penn	2.346	146.6	1+ 28	850	900	950	1000	1000
19	Potsdam Sandstone	Beauharnois, P. Q	2.512	157.0	1+ 38	850	900	950	1000	1000
20	Sandstone	Murray Bay, P. Q	2.577	161.0	1+ 36	900	950	1000	1100	1100
21	"	Cheat River, W. Va	2.632	164.5	1+ 80	800	850	900	1000	1100
22	Freestone	Acqua Creek, Va	2.183	136.4	1+ 16	900	950	1000	1100	1200
23	Brown Stone	Manasses, Va	2.348	146.7	1+ 17	850	900	1000	1100	1200

CONGLOMERATES.

1	Conglomerate	Roxbury, Mass	2.708	169.2	1+49	700	800	900	1000	1000
2	Potomac Stone	Point of Rocks, Md	2.724	170.2	1+60	600	700	800	900	900
3	Conglomerate	Cape a La Aisle, P. Q	2.645	165.3	1+80	600	700	800	900	900

MARBLES.

No.	Kind.	Locality.	Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	First appearance of injury.	Crumbles or cracks, slightly.	Cracks, badly, or becomes friable.	Injured so as to be worthless for a building.	Melted or ruined.
						Deg. Fah.	Deg. Fah.	Deg. Fah.	Deg. Fah.	Deg. Fah.
1	Tuckahoe	Westchester Co., N. Y.	2.794	194.6	1+298	900	1000	1200	1200	1200
2	Ashley Falls	Ashley Falls, N. Y.	2.742	171.3	1+280	900	1000	1100	1200	1200
3	Snow Flake	Westchester Co., N. Y.	2.848	178.0	1+380	950	950	1000	1200	1200
4	Tennessee	Dougherty's Q'y, E. Tenn.	2.711	169.4	1+320	950	950	1000	1200	1200
5	Duke Marble	Near Harper's Ferry, Va.	2.812	175.7	1+340	1000	1000	1100	1200	1200
6	Black Marble	Isle La Morte, Vt.	2.682	176.6	1+320	1000	1000	1100	1200	1200
7	Sutherland Falls	Rutland, Vt.	2.666	166.6	1+342	1000	1000	1100	1200	1200

SLATES.

1	Sabin's Quarry	Montpelier, Vt.	2.869	179.3	1+110	800	850	900	1000	1200

SOAPSTONES.

1	Soapstone	Weathersfield, Vt.	2.668	166.7	1+3 8	1200	....	....	....	....

ARTIFICIAL STONE.

1	Artificial Stone	McMurtire & Chamberlain's patent	2.235	139.7	1+280	750	800	1100	1200	....

OUR CENTER OF POPULATION.

By FRANK D. Y. CARPENTER, C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

IF a man in San Francisco and another living in New York should wish to hold a conference, it requires no mathematical demonstration to prove that the proper place for them to meet would be at a point half-way between these two cities. In this manner the burden of travel is shared equally between the two. But, if one man in San Francisco and two men in New York should desire to come together, the subject becomes more involved. It is evident that it would be unjust to require the solitary Californian to perform the entire journey across the Continent to meet his colleagues at their homes, and it would be equally unfair to oblige the two New Yorkers to travel half-way to San Francisco to confer with one person from there. The question is, how great a penalty should the former pay for his isolation, and how much benefit should the latter reap from their association?

An equitable compromise is effected by apportioning the distance in inverse ratio to the number of persons concerned. The one from San Francisco travels two-thirds of the distance while the two from New York come one-third. Thus, it will be observed, the amount of travel on each side of the rendezvous is equal; that is, one man journeys, say, two thousand miles, while the two accomplish one thousand each. In other words, to introduce from the science of mechanics a term which it will frequently be found convenient to use in this discussion, the moment of the man from San Francisco about the rendezvous is equal to the moment of the two men from New York with respect to the same point. The west moment is in equilibrium with the east moment, and the fulcrum about which they balance is the center of this population of three persons.

A moment is the product of a force by its shortest distance from some point, line or plane, to which it is referred, this distance being known as the leverage. The intensity of the force and the length of the leverage are counted in certain established units of weight and measurement. In the subject now under treatment the forces considered are the individuals of our population; and since all people, rich and poor, large and small, ignorant and learned, infant and adult, male and female, are of uniform importance in swelling the grand total of an enumeration, these forces are taken as of equal intensity, and their moments vary directly with the lengths of their lever-arms. In ordinary mechanical investigations the value of a moment is estimated in foot-pounds, the product being named from its component factors; a corresponding and appropriate term with which to measure the moments of this special discussion would be "milemen."

If, now, with the one Californian and the two New Yorkers aforesaid, we combine groups of three from Chicago, four from New Orleans, and, to make the problem still more complicated, five from the central city of Saint Louis, it is still possible to find, by the appliance of well-known principles in mechanics, some point at which they could assemble with justice to all, and that would be the center of this population of fifteen souls. It is only necessary to assume a center, draw a system of rectangular axis through this point, find the moments of the fifteen persons with regard to each of these two lines, note the preponderance of moments on one side of each of the axis, divide this surplusage by the entire population under discussion, and the result will be the amount of displacement of the axis from its rightful position. Adjust these lines so as to compensate for that error, and their intersection will be at the true center of population.

This is the general method to be employed in finding the center of population of the country at large. But as it would be an infinite labor to consider its fifty millions of inhabitants individually, determining their moments one by one, it becomes necessary to handle them by groups, such as states, counties, town-

ships, or square degrees, proceeding upon the assumption that the people of each of these groups are massed either in the geometrical center of the area occupied by them, or at some other point which, from an inspection of the map, aided, perhaps, by local calculations, seems to be their population center. Whatever divisions of area may be adopted for this purpose, it is always well to obtain separately the moments of those cities which, owing to size or remoteness from either axis of co-ordinates, will exert most influence on the center; the gain in accuracy will more than repay for the extra trouble incurred.

The center of population of the United States may, therefore, be defined as that point at which, if all of the people should assemble there, the amounts of travel performed on any two sides would balance; in less popular language, the moments of the population with respect to any great circle passing through that point, taken as an axis, are in equilibrium. It may sound strange to call an arc of a circle an "axis," but in the treatment of a new subject like this, it is permitted to take some liberties with language; in the words of King John to Katharine: "We are the makers of manners."

A knowledge of the whereabouts of this pivotal point is useful in various ways. It has a practical value in the location of a national capital, university, industrial fair, or other institution whose situation should be central and equally convenient of access on all sides. To the historian and political investigator its successive positions, as shown by census after census, graphically exhibit the movement and advance of our people in a wave which is at one time accelerated by the settlement of the Pacific coast, in the next decade checked by the loss of life and enterprise incident to our civil war, deflected to the North in 1870 by the excessive devastation of the Southern States; again to the South in 1880 by the rapid recovery and growth of that desolated region, and probably to be turned northward again in 1890 by the occupation of the region to be opened by the Northern Pacific Railway, and by a rush of emigration to the mineral regions of Alaska, and the establishment of a territorial government there. Through all of these vicissitudes, however, there is a constant progress to the West, and, its recurring positions upon a map being ordinarily symbolized by a star, this conventional sign becomes literally the star of empire of whose westward way so much is written and said. It is now in Ohio.

The center of the population of any portion of the earth's surface has been aptly compared to the center of gravity of a spherical shell of equal extent, having weight, in any locality, in proportion to the density of its population; but fortunately the determination of the former center is not so intricate a problem as that of the latter would prove to be. In all ordinary discussions of the center of gravity, the objects considered are so limited in dimension that the forces of gravitation may be supposed to act in parallel lines; but in treating a section of the earth's area, one-eighth of a circumference in extent, this assumption can no longer be permitted. Here gravity acts along the normals to the surface, which converge, approximately, at the center of the earth.

Again, even supposing that the forces of gravity influencing this spherical shell acted in lines parallel to each other, and to the normal to the surface through their center, the moment of each of these forces would then be the product of its intensity by its perpendicular distance from the center; that is, by the sine of the arc included between its point of application and the center. But, in getting the center of population, it is evident that the leverage to be taken as a factor in obtaining the moment of any group of people is the distance that they would have to travel in order to reach that center. People do not travel along the sine of an arc, however; they follow the arc itself, and in theoretical journeys, as all of the migration of this discussion must be, they take the shortest route, that is, the great circle.

By thus considering that all leverages reaching from the center of population, or the axis passing through the same, to the distant city or state, are measured along the earth's surface, we are relieved from one of the embarrassments which affect the determination of the center of gravity; and by further assuming that these measured arcs are stretched out

and coerced—as best can be done—into a plane surface, tangent to the earth at the center of population, the various normals, now normal to the same plane, become parallel lines, and the center of population becomes a center of parallel forces.

Thus simplified, it is not a difficult task to determine this center. But there is a flaw in this process. It results from the impossibility of representing a spheroidal surface upon a plane and preserving all areas, proportions and distances in their true values; in other words, the surface of our spheroid is not capable of development. When it is remembered that the leverages which enter as factors into the various moments are distances upon the earth's surface, it will be seen that a true expression of them is necessary for a rigidly accurate determination of the center of population. Such an expression can only be found by a computation of the lengths of the arcs which constitute these lever arms.

Since the center of population is that point about which there is an equilibrium of moments, there must also be equilibrium with respect to any two rectangular axes which may be drawn therethrough. Upon the earth's surface these rectangular axes become two great circles perpendicular to each other. It is obviously most convenient to adopt for this purpose the meridian through the assumed center, and its perpendicular, which is the prime vertical at that point. It would now be necessary, in the method under contemplation, to compute the leverage of every group of population with respect to each of these axes. This leverage is the shortest distance from the group to the line aforesaid; that is, an arc of a great circle perpendicular to the axis. So laborious a process as this, involving so many computations in geodesy and spherical trigonometry, is manifestly impracticable and quite out of the question, and is mentioned here only because of the theoretical interest it may possess.

To return to the graphic and approximate mode, it is possible to construct a map of our country in such a manner, that the leverages taken by direct measurement from the perpendiculars let fall from the local population centers to the assumed axes, will give a national center whose probable error, resulting from the inaccuracy of the method employed, will be less than the other error arising from the crude but inevitable custom of handling the population by communities instead of by individuals. Any greater precision than this is not worth the immensely greater labor that it would cost. It is now the object of this article to propound some way, sufficiently rapid to be practicable, of attaining this degree of exactness.

As has been said, the spherical shell must be considered as a plane surface. But there are numerous ways of doing this. Every style of map projection is a transformation of this kind, and, unfortunately, every one involves some displacement, distortion, or expansion or contraction of areas and distances. We now seek a projection which will incur a minimum amount of error in dimensions and relative positions, and whose conditions will thus be most favorable for the work at hand.

As the leverages are to be the perpendicular distances from the local centers to the great circle axes, it is important that these great circles should appear on the map as straight lines, intersecting at right angles at the assumed center; or, failing in that, that they should approach as nearly as possible to rectilinearity. Cassini's projection is the only one known to the writer in which these two great circles would be projected into right lines; but this method is attended by so many disadvantages—among others the obliteration of our convenient division of a country into square degrees by its reticulation of meridians and parallels—that it may be dismissed from further consideration.

In the polyconic projection, taking the middle meridian through the assumed center and making it one of the axes, it will be projected into a right line, while its co-ordinate axis—the prime vertical—will not depart far from the same auspicious condition; its greatest deviation from rectilinearity within the limits of the United States would not exceed forty miles. This will not produce a curvature that will materially interfere with the process of drawing perpendiculars to it from the local population centers. The principal argument against the use of the polyconic projection in this work is

that uniformity of scale is not preserved, it being sacrificed in order to retain a natural angle of intersection between meridians and parallels. Thus any two parallels of latitude on the map, instead of being concentric, and therefore equidistant throughout, as they are upon the earth's surface, separate more and more as they leave the middle meridian. With the middle meridian passing through Ohio, a projected degree of latitude in Oregon or Maine is much longer than in Michigan. In this way the population of those remote northwest and northeast regions will be given greater north leverages than they are entitled to, and the resulting tendency will be to draw the national center unduly northward.

The preceding method is given for what it may be worth. It possesses at least the merit of convenience, as the data for the polyconic projection of a map are widespread in this country, and draughtsmen are familiar with their use. Moreover, with all of its faults, it is warranted to give results much more accurate than any hitherto attained.

Finally, we come to the consideration and adoption of Bonne's projection, which is by all odds the best adapted for delineating a portion of the earth's area, so that, having allotted weight to this map according to its density of population, the center of gravity of this plane will most accurately represent the center of population of the spherical surface.

In Bonne's projection, as in the polyconic, the middle meridian becomes a straight line. The central parallel, also as in the polyconic, is projected in the arc of a circle whose radius is equal to the slant height of a cone, tangent to the earth at this parallel, and of whose base this parallel is the circumference. All other parallels are concentric with the middle one, and are drawn at their natural distances apart. All lengths of parallels are also correct. An equality of areas, upon the earth and on the map, is thus preserved, although the shape of those square degrees remote from the middle meridian and parallel becomes distorted, and rhomboidal, their diagonals being unequal, owing to the oblique intersection of meridians and parallels. This fault is of but little importance in the present work, where the principal desideratum is uniformity of scale with regard to the axes, and hence correct relative positions, in which respect no other projection offers equal advantages. Add to this the fact that the projection of the prime vertical through the intersection of middle meridian and parallel scarcely deviates from a straight line, its departure from rectilinearity within our boundary not exceeding ten miles, and the fitness of Bonne's projection for a population map is assured.

Therefore, to find the center of population of the United States, first assume a center from an inspection of the map or from rough preliminary calculations. It is important that the assumed center should approximate in position as closely as possible to the true center, so that the rectangular great circle axes through the former may be considered parallel, for the portion included within the United States, to the corresponding system through the latter, to which the first axes are to be shifted in the final adjustment. Make the assumed center the point of intersection of the middle meridian and parallel of a map projected after Bonne's method, and divided into square degrees. This map need not be drawn in detail. Outlines, boundaries, and the positions of those principal cities which are to be treated separately will suffice. Local centers of population may be taken from any ordinary map and transferred to this.

Draw through the assumed center the projection of its prime vertical, tracing its course by computing the latitudes of its intersections with meridians which it crosses. With this as one axis, and the rectilinear projection of the middle meridian as its co-ordinate, proceed to find the moments, with respect to these axes, of the numerous collections of people into which it may be deemed advisable to divide the country. Under the direction of Mr. Henry Gannett, the very efficient geographer of the Census Bureau, the population of the United States has been grouped by square degrees, and, it is to be hoped, will be published in that form. Such an arrangement will greatly facilitate all studies concerning the geographical distribution of our people, and will be especially useful in finding the center of population. A determination of the center by the use of square degrees and the leading cities will re-

quire about one thousand moments for each of the two axes. The leverages of these masses will be their perpendicular distances, measured on the map, from the axis in question. There is, to be sure, a slight element of error in this manner of finding the value of an arc of a great circle, but it is so inconsiderable that it will not perceptibly affect the result, and it would be a thankless task to attempt to eliminate it.

After the summation of the moments thus found, and a comparison of the results, east with west, and north with south, the adjustment of the center to its true position is accomplished as described in the early part of this article.

In determining the center of population hitherto it has been customary to accept, for the rectangular axes through the assumed center, the meridian and parallel intersecting at that point; that is, a great circle and a small circle. Leverages of the population masses with regard to the parallel have been measured along their respective meridians, and are therefore arcs of great circles, as they should be; but the leverages about the meridional axis are the arcs of parallel intercepted between the local centers and that axis, and are, in comparison with the proper lever-arms, as the hypothenuse is to the perpendicular.

A moment's contemplation will show that this is equivalent to adopting, for the axes of a plane, a straight line and a curve intersecting at right angles, and then using curved instead of perpendicular lines for the leverages with respect to the rectilinear axis. Of these two erroneous processes, the latter will cause the center a slight displacement in longitude, while the former will seriously affect its position in latitude, throwing it many miles too far southward.

As heretofore determined, all north leverages are deficient and all south leverages are excessive, except those lying along the meridian of the center. The greater the distance of a group of population from this meridian, the greater is the error of its moment. On the Pacific coast, for instance, the parallel of the center of population is more than four hundred miles distant from the prime vertical passing through that point. The leverage of any group of population, by the old method, is erroneous to that extent. As an example, the city of San Francisco is nearly a hundred miles south of the parallel aforesaid, and has been given a south leverage of that amount, when, in reality, it should have a north leverage of more than three hundred miles. In the same manner, all other north and south moments are invalidated by this fault of accepting a small circle instead of a great circle for an axis.

The west leverage of San Francisco is also as much too large as its distance from the meridional axis by arc of parallel is longer than by an arc of great circle. But these excessive leverages in the west are partly compensated for by a corresponding excess in the east, and the resulting error in the longitude of the center is not so great; a mile or two would probably cover it. It is difficult to estimate, from a mere inspection of the map, how great an error of latitude may affect the center of population, as determined by the old method, but the center, thus found, of the population of 1880, falling in northern Kentucky, a few miles west of Covington, its true position is probably about thirty miles farther north and a trifle to the east; that is, in Butler County, Ohio.

It may seem improbable that the center should lie so near our northern boundary, but it should be remembered that our country, in general shape, is the segment of a zone, and if this segment were extended far enough in longitude its center of population would be situated entirely outside of the country, beyond its northern limit.

The difference between the plan herein proposed and the one hitherto followed, in determining the center of population, may be graphically illustrated by a comparison of Bonne's and Flamsteed's projections of a map. The latter is an exact counterpart of the plane surface into which the spherical shell is supposed to be projected in the old method; that is, its parallels occur at their natural intervals, but are straightened out into right lines, all of which are perpendicular to the middle meridian, itself a straight line. The middle parallel is taken as one of the rectangular axes, both of which, upon the map, are rectilinear. Thus this process has a plausible

appearance, until it is remembered that the distortion of this parallel into a right line necessitates a great curvature in the projection of the corresponding prime vertical, which is the real axis, and a great displacement of areas. Flamsteed's projection, therefore, while it is easily comprehended by the popular mind, which is accustomed to consider our country as a plane surface, across which east and west courses run in straight lines, is really one of the most untrue in existence.

In thus criticising past dealings with this subject, the writer does not flatter himself that he has discovered an unconscious use of faulty methods in the work of the able investigators who have preceded him in the study of this matter. Taken at the best, its treatment must be approximate, and hitherto the newness of the subject, an absence of popular interest in it, the pressure of more important work, and other exigencies of the public service, have combined to preclude any other than the most convenient and least laborious handling of this topic. It may even be doubted if, at the present day, it is advisable to bestow upon it the increase of labor entailed by the project announced in these pages; but in the future, as our methods of work become more and more refined, and especially as our northwest country and the Pacific Coast, remote from the center, become thickly populated, and the error of their influence upon the center is correspondingly increased, it will certainly be found necessary to attempt a closer approximation than has yet been accomplished.

The old plan has an advantage of convenience in the fact that all distances along the meridians and parallels of our country, which are the leverages therein used, are already computed and tabulated in geodetic handbooks. And, although the absolute situation of the center is not accurately given by that method, it shows correctly its relative positions, decade after decade, and its constant westward migration with its fluctuations to the north and south.

Through the enterprise of the Hon. Francis A. Walker, Superintendent of the Census Bureau, the center of population was made an interesting feature of the census reports for 1870, and will, doubtless, find a place in all future discussions of the movement of our restless people. By computations made under his direction, and by independent determinations contributed by Prof. J. E. Hilgard, of the Coast and Geodetic Survey, he was enabled to locate, upon his population charts, the successive positions of the center for each decennial period from the year 1790, when it was east of Baltimore, to 1870, when it had reached a point in Southern Ohio, forty-eight miles from Cincinnati. For the details of its progress the reader is referred to the chapter by General Walker, entitled "The Progress of the Nation," in his valuable Statistical Atlas of the United States, and also to an article by Professor Hilgard, published in *Scribner's Monthly* for June, 1872, under the heading of "The Advance of Population in the United States."

From these authorities it seems that the migration of the center of population, almost uniformly westward, has been at an average rate of fifty miles a decade, five miles a year, or seventy-two feet a day. This, then, is the measure of the progression of that imaginary, but important point, the "hub" of the United States, which is destined to move, with slower and slower pace, until it shall reach, a century hence, the immediate valley of the Mississippi, where it will permanently settle. Though the West grow strong at the expense of its parent, the East, and the one flourishes as the other becomes effete, this shifting of power is no sudden and startling process, as will have been seen. The emigrant's ox-team, the type of all things slow, and by which this transfer of empire has been largely effected, outstrips a thousand fold the center of population in its advance.

It has been judicially decided in the American law courts that a mail agent, or traveling post-office servant, when traveling as such on railroad trains, is not a passenger, and cannot therefore recover damages for injury in case of accident; also, that a passenger riding in a baggage car when there is room in the passenger cars cannot recover in case of injury, if it shall appear that he would not have been injured if he had been in the passenger cars.

NEW MODE OF COMPENSATING BALANCES.

By CHARLES V. WOERD, Sup't Engineer of Waltham Watch Company.

THE form of compensation hitherto employed in the balances of watches and chronometers can be made perfect only for two critical temperatures, and is imperfect for intermediate or extreme temperatures. Devices called secondary or auxiliary compensation have been applied to remedy this defect in a partial degree. The effect of the temperature is to modify the elastic force of the spring as well as to change its length, and to change the form of the balance; and perfect compensation requires that the time of vibration of the balance shall be constant under all the vicissitudes of temperature to which the instrument may be subjected. This requires that an arrangement of the parts shall be made such that the moment of inertia of the balance shall maintain a constant ratio to the moment of the elastic force of the balance spring. The law of the change of the effective elastic force of the spring is not certainly known; but sufficient is known in regard to it to make it certain that the compensation cannot be made perfect except at two temperatures. The expressions of the variations of these moments in respect to the temperature, give, when graphically represented, two curved lines, and the adjustment can be made only for the two points where these curves intersect.

Fig.1

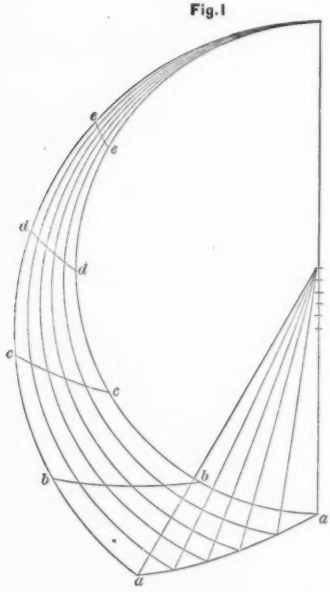
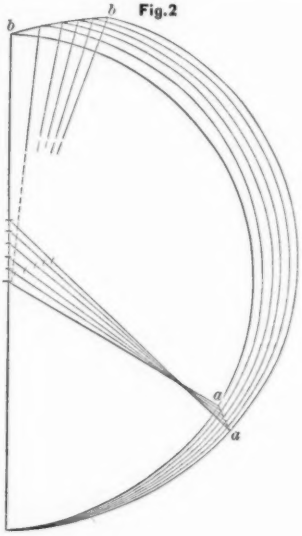


Fig.2



The device consists in the substitution of an entirely different arrangement of bimetallic laminæ, in such a way that the ratio of the moments of the balance and of the spring shall remain constant during all the temperatures to which the watch or chronometer may be subjected while in use.

First, for the inner lamina steel is employed as usual, but the outer lamina is constructed of a composition of higher expansibility than brass hitherto used

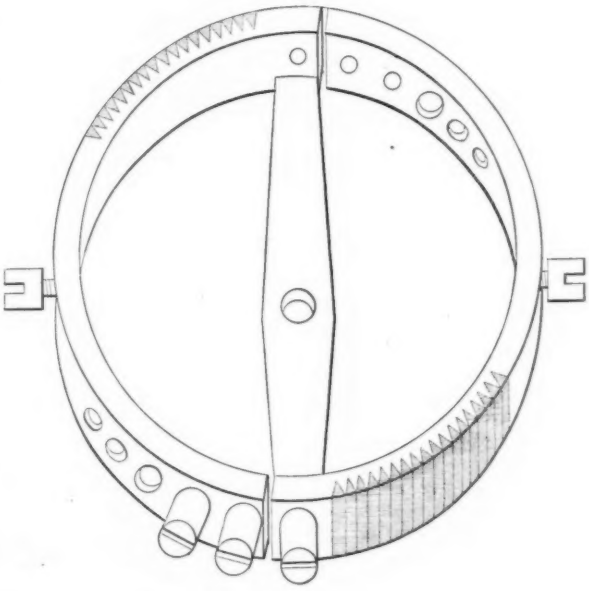
for that purpose. Instead of two parallel connected laminae, only a short arc of the outer composition is employed, and this is connected with the steel in the form of intermeshing teeth fused solidly to the steel. The outer rim is turned down so that the fine edge of the steel teeth separate the composition into a succession of prisms.

By this means the action is different from that of continuous bimetallic laminæ, in that it avoids the difficulties arising from the constrained and irregular action of the laminæ, and provides for that freedom of movement of the compensating weights which is necessary to fulfill the actual requirements of the adjustment for temperature.

Second, by means of this arrangement it is always possible to find the number of teeth in the bimetallic part of the rim which, in connection with the proper compensating weights, will make the motion of these weights correspond with the requirements of the balance spring for tautochronous vibrations at different temperatures. In order to lighten the steel rim and keep the effective weight of the balance as near the extremities of the segments as possible, one or more holes are drilled in this steel rim, and intermediate between the bimetallic part and the compensating weights, so that the desired effect may be produced by a limited arc of the two metals. This provides also for a delicate adjustment of the poise of the balance.

Fig. 1 represents the movement of the compound laminæ under a decrease of temperature in the form of bimetallic compensation hitherto used. The inner

Fig. 3



curve represents the rim of the balance at a middle or normal temperature. The outer curves represent its successive positions at diminished temperatures, and the oblique lines *a*, *a*, *b*, *b*, etc., show the motion of the compensating weights placed at different positions of the rim. The curves described by these weights do not in any case change the moment of inertia of the balance in the required ratio and the compensation is therefore imperfect.

Fig. 2 represents the motion of the rim of the balance when constructed in accordance with this device. The inner

curve shows the normal position at a middle temperature, and the other curves show its motion under successively diminished temperatures. The curved line *aa* shows the path of the extremity of the bimetallic arc, and *bb* shows the curve described by the compensating weights at the outer extremity of the segment. The proper number of teeth in the bimetallic part to correspond with the thickness of the continuous steel rim, to be easily found in the actual adjustment, will give to this curve the form which is required in order that the rate of change of the moment of inertia of the balance shall be always sensibly the same as that of the moment of the elastic force of the balance spring, so that the compensation may be made practically perfect.

The forms and relation of the curves in the two cases will be similar when the temperature is increased from the normal temperature considered.

Fig. 3 represents the balance complete, constructed in accordance with this device. The steel arm of the balance is represented at *a*. The steel portion of the rim is shown by the light portions, and the composition for the outer part of the bimetallic portion of the rim is indicated by the lined parts. The number of teeth depends upon the thickness of the rim, and should include in general about one-sixth part of the circumference. The rim is cut very close to the extremities of the arm of the balance, and the compensating weights are placed near the outer extremities of the segments. The small holes shown intermediate are made in order to keep the resultant action as far as possible from the bimetallic part of the rim.

RECENT ADVANCES IN ELECTRIC LIGHTING.

By W. H. PREECE.

From the "Journal of the Society of Arts."

I AM to describe to you the recent advances that have been made in electric lighting. My position reminds me of a story that is told of Queen Elizabeth, who, on approaching a certain town, was not received on arrival with the usual ringing of bells. On demanding the cause, the chief municipal dignitary informed her Majesty that there were 39 reasons why the bells did not ring, the first of which alone satisfied her Majesty, viz., "there were no bells." So I can almost say "there are no recent advances in electric lighting to chronicle." The advances that have been made have not been so much in electric lighting itself as in the popular favor with which it is regarded. The public is becoming more accustomed to its use, and therefore acquiring more confidence in this mode of producing light.

Electricity and gas are playing a see-saw game. As the electric light goes up, the gas goes down. It reminds one very much of those old Dutch weather houses that used to be common many years ago, but have recently disappeared. When the weather was fine, out came the old woman; when the weather was damp, out came the old man. Electricity made a great splutter in Paris; down went the gas shares. Mr. Sugg and his inventions brought the gas shares up again. An alarming message is received from New York; down goes the gas again. The friends of gas have scarcely had time to recover themselves when the City of London, with great wisdom and foresight, votes a very large sum of money to be expended in carrying out a gigantic electric lighting experiment, and this has brought the old man out once more.

The result of trials during the last year or two have been to give experience in the vagaries and capriciousness of this light. Its defects have become better known. We have been taken out of the experimental, and have been brought within reach of the practical stage. Now details are being elaborated, mechanical appliances supplied, and much useful knowledge is being acquired by those who have had the enterprise and

the farsightedness to launch their money in this new venture.

The progress of electric lighting can be looked at from three points of view—scientific, commercial and practical.

My task has been rendered very light, by the admirable series of Cantor lectures that have recently been delivered in this room by Professor Adams. He has thus enabled me to shake myself away from scientific detail, and to deal more with commercial and practical generalities. I will, therefore, glance rapidly at the commercial and practical developments of the principal portions of the system which together make up electric lighting. Let us first take the motor, the power by which scientific skill has enabled us to convert a source of energy into another form. The problem we have to solve is how to extract the greatest amount of light out of a lump of coal. Of our agents to help us, the poor old engine is much neglected. When I think of the work done by that willing slave, the engine, I am reminded of the story of the organist and the organ blower. The blower one Sunday said to the organist: "How magnificently we played Handel's . . . to-day!" "*We* played," replied the organist, "you impertinent fellow, what do you mean by "we played?" The blower said not a word, but on the next occasion when the organist wished to play, the blower declined to exert himself, and on being remonstrated with, he said: Do we play, or do we not play?" The organist said: "Yes, we do play," and instantly the organ pealed forth. So with the engine, where should we be without the engine? The reason why the electric light has, within the last few years, come so much to the front, is because electricity has been produced by the direct conversion of mechanical energy into electricity, instead of by means of batteries, which were the only sources known years ago. Now, thanks to the steam engine, we are able to fulfill all those requirements that enable us to produce cheap electricity. Those requirements are high velocity, great steadiness, and uniform pressure; and those are the points which are gradually being acquired in the steam engine produced from our workshops. The velocity of 800 revolutions per minute, sometimes even of double that rate, is an enormous velocity to maintain, but it is essential for cheap electricity. Eight hundred revolutions a minute need not frighten us, for we care not what the speed of rotation is in the wheels of our express trains. No one troubles his head much about the tremendous velocity acquired by a carriage that runs continuouly for 24 hours or more, and, therefore, we need not be alarmed at the velocity acquired by our stationary engines working electro-dynamo machines. It is not too much to say that what little success belongs to the electric light on the Thames Embankment, is due to the engine planted beneath Charing-cross bridge, by Messrs. Ransome, Sims and Head.

Nor should I say that the success of the electric light in the British Museum is due any the less to the Wallis and Stevens' engine than to the magnificent apparatus put up by Siemens Brothers. It would be invidious to name the different engineers who have brought out special engines for this purpose, for their name is legion. Marshalls, Brotherhoods, Robey, and others have worked hard in this field, and have succeeded in producing engines which, by automatic governors and by other means, provide all the requirements that the electric light demands. It would be difficult to over estimate the good that has been done in this direction by the competitive trials instituted by the Royal Agricultural Society. The small engines that distinguish English engineers, are almost entirely due to the interest excited by these annual trials. Instead of one-horse power requiring 7 lbs. and 8 lbs. of coal to produce it, it is common now to find engineers producing one-horse power by even 3 lbs. of coal, and in some engines 2 lbs. per horse-power has even been attained. It is strange that nothing has been done to supersede steam as a generator of power. It is well known that the specific heat of water is higher than that of every known substance, and is not beyond the reach of theory to assert that there are other liquids whose evaporation should produce the same power with a very much less expenditure of fuel. There is a vast field for invention in this direction. The gas engine is a very economical source of energy, and has been very successfully applied to

electric lighting in many places. At the Docks in Newport, South Wales, a gas engine has been in use for nearly two years with great success; and it is worthy of note that if 100 cubic feet of gas per hour gives a candle power of 300, that same gas applied to an engine would give, in electricity, a candle power more than 11 times greater, namely, 3,750 candles. Here is a sphere to maintain gas dividends.

Water is another convenient source of energy, when you can find it available. Sir William Armstrong, at Craigside, near Newcastle, has utilized a brook for this purpose, and, by the aid of a turbine, produces a force giving six-horse power; in fact, he says: "The brook lights his house."

I am not aware yet of air having been utilized for this purpose, except when heated in the caloric engine in use at the Lizard Lighthouse, which is found to be economical, useful, and very suitable for such isolated places where it is difficult to provide water. It is, therefore, clear that some advances have been made in the economy and the adaptability of motors for electro-dynamo machines to produce the electric light.

With regard to the generator of electricity, the instrument by which the energy of steam or water is converted into electricity, after Professor Adams not much remains for me to say. There are several excellent machines. The difference between each is very much the difference between tweedledum and tweedledee. Each is specially adapted for its particular work, either by a variation in velocity, or by a variation in the way in which the wire is wound, so as to produce a variation in the current produced to suit the particular light required. The efficiency of any machine is the amount of energy which is converted into current, and it has been shown that both in the Siemens and the Gramme machines nearly 90 per cent. of the power is converted into useful current. It is easily demonstrable that there is economy in the use of small machines, and it is difficult to understand the reasons that induce some people to speak of the value of the enormous machines that have been constructed in America. In fact, in this department, a great deal of time and energy is being wasted in trying to gild refined gold. Changes are being introduced for the mere sake of change. The improvements that have been made have been improvements in detail only. Broadly speaking, there are two classes of machines, those which produce continuous currents, and those which produce alternate currents. Very little advance has been made in the efficiency of the earliest forms in every case; and I learn from Mr. Douglass, of the Trinity-house, that the original Holmes magneto-electric is still in use, and doing good work, at the Souter Point and South Foreland lighthouses, and that a De Meritens magneto-electric alternating current machine, of similar type, has been under trial at the Lizard for the last four months, and that he is greatly pleased with its efficiency and reliability. The De Meritens machine is an excellent one, and one of which we shall hear more. The trials made for the Trinity-house showed that more efficiency was obtained by joining up small machines in multiple arc, than either by the use of a larger machine, or by the same machines joined up in series. This is a point that has escaped the notice of recent experimenters in this direction, and it is well worth their serious consideration.

The battery has been discarded as a generator of electricity from its want of economy, but there are hopes that secondary batteries will be introduced for the purpose of storing up this force. No advance has yet been made, however, towards the practical attainment of this desire. Many attempts have also been made to utilize the thermopile, but in all cases it has been shown that the electromotive force produced is too low. The thermopile has this advantage, that it is wonderfully durable. I saw, last week, one which has been in use for four years uninterruptedly, night and day, without intermission, and it still gives out electricity with all its pristine vigor.

The conductor is the broad road along which electricity flows to produce light at a given point. In all cases, from its superior conductivity, copper has been selected. Sometimes this copper wire has been carried overhead and sometimes underground. Where it can be carried overhead, it has the advantage over underground that, as the heat radiates into the open air, the wire itself becomes

cooler and conveys more electricity. In practice, the purest copper is used, and wire of the largest dimensions consonant with economy, for the resistance or obstruction to the flow of electricity must be maintained as low as possible, to prevent waste of energy. In the different experiments which have been carried out in London, one feature noticeable to me has been in some cases the utter ignoring of the experience gained in telegraphy. The way in which wires are suspended, and hung, and moved about, is to the mind of the telegraphist simply disheartening and appalling. On the Metropolitan Railway the wires were so decayed, and rotten, and ill-used, that they had to be removed, and the lighting of the Victoria station of the underground railway was abandoned. The currents used for electric lighting are more than three thousand times greater than those used for telegraphs. We have great difficulty in maintaining the small currents used in telegraphy along their proper course, and the small defects that have, in thirty years' experience, made themselves evident to us, are simply magnified in their hurtful effects 3,000 times when applied to electric lighting currents.

Electric currents have also a peculiar and serious influence on wires passing in their neighborhood. It is an influence called induction, and one that produces serious disturbing effects. In fact, so powerful are these disturbing effects that very great fears are entertained that it will be impossible to maintain electric light and telegraph circuits close together. Recently, at Holyhead, telegraph communication was completely broken down along a wire that ran side by side with the wires conveying an electric light, during the time the current flowed to produce the light. We of the post office are watching carefully for any interference by electric light currents in this respect.

Why do electric currents produce light? Light and heat are mere terms given to what are really similar operations. Certain undulations impinge on the retina of the eye, and give that sensation which we call light. They fall on our skin, and produce the sensation of warmth. They are incident on certain salts of silver, and produce photographic pictures. The flow of electricity means the generation of heat. The production of light is the accompaniment of intense heat. In fact, the brighter the light, the intenser the heat. The art of producing brilliant light is the art of pro ducing high temperature. There is no greater illusion extant than that the electric light is a cold light. The electric arc is the greatest source of heat known. Our worthy chairman has shown us how it can reduce to liquid the most refractory metals; and at his country house, near Tunbridge Wells, he has kept a stove house at 70° by its aid. Professor Dewar measured the heat radiated by the light he used, and found it sufficient to produce three-horse power per minute; hence electric currents produce light because they produce intense heat.

Now, this heat can be produced either by causing the electricity to fly across an air space, in which case we have light by the arc, or by causing it to flow through a small wire, or a carbon filament, which offers obstruction to the flow, and produces light by incandescence.

We have burning to-night several specimens of each kind. The forms of arc lamps are very numerous. In every case carbon rods are opposed to each other, and they are disintegrated and consumed in the fierce blast to which they are subjected. The lower pole—the negative—acquires a temperature of 3,150° C., it is broken up and fired with a fierce bombardment of white hot molecules across the air against the upper pole —the positive—which is beaten up by incessant impacts into a higher temperature of 3,900° C., the arc itself being 4,800° C. On account of the irregularity in the character, and, therefore, the consumption of carbon, and the variation in the strength of the current, various ingenious appliances have been adopted to obtain steadiness and uniformity in action. Mechanism, clockwork, electro-magnetism, gravity, and all kinds of contrivances have been called in; in fact, of arc lamps, their name is legion.

A remarkable attempt was made by Jablochkoff to dispense with mechanism altogether in his candle, but though many thousands of them are in use, it is doubtful whether the candle system will be permanent, for it is expensive and

wasteful. M. Jamin has recently taken a step in advance in this line, and the trial of his lamp is being eagerly watched.

We have not yet obtained perfection in the arc lamp. We want brilliance, combined with absolute steadiness, and the durability of a winter's night. Great steps have, however, been made in simplification of parts and smoothness of action; but we lack silence and steadiness.

Many of the defects of the arc light are compensated for in that of incandescence. Here we have something that is beautifully soft, absolutely noiseless, perfectly steady, a light that brightens up nature in all her true colors and purity. I shall not readily forget a dinner party given by Mr. Spottiswoode, the President of the Royal Society, a short time ago, when his room was illuminated by Mr. Swan's lamps. It was not only fascinating, but fairylike and lovely. One felt in a dream. We have had a sample of it here, and the beauty of the light grows on you. The incandescent light is, however, at present, an expensive luxury. It requires a considable expenditure of power. For instance, Sir W. Armstrong finds that six-horse power supplies 37 lights, giving altogether 925 candles. Six-horse power in arc lights would give over six thousand candles. However, we must not grumble. Rapid progress is being made in this field. Maxim, Edison, &c., in America; Swan, Lane.Fox and others, in England, are working hard, while Gordon and Joel are working in an intermediate field, where a prospect appears of a happy compromise being effected between the arc and incandescence. We have, to-night, an illustration of the burning of the Joel lamp—a modification of that introduced by Mr. Werdermann.

A good many wild statements are made about the light-giving power of these different lamps. A standard sperm candle may be a very good unit to measure gas by, but it is a very poor standard for the electric light. Of course the advocates of the electric light overestimate their case. It would not be human nature if they did not; but their divergences are wonderful. Thus, the Glasgow committee makes one horse-power produce 600 candles; the Trinity House, 1,254; a Paris commission, 2,500; a certain Anglo-American Light Company, an unknown quantity!

We have two natural standards to refer to, sunlight and moonlight. We have various physical forces to appeal to for measurement, photographic records, the production of heat, the estimation of shadows, &c., but the standard of the future remains an *ignis fatuus*. To estimate the value of a light, you must not look at it; you must turn your back to it; you must try and read small print by it, and then you will find what a godsend it would be to find some means by which we could estimate the illumination of a square foot or a square yard. We want not only a new standard of light, but we want a new system of photometry. Efforts have been made to estimate the intensity of the light radiated by the size of the craters found on the carbon rods; but this mode of measurement is empirical and illusory, for it varies with the character of the carbons and the currents used.

A word about that "philosopher's stone," that *elixir vitæ*, the subdivision of the electric light. What does it mean? It means that certain gentlemen hope, from one central spot, to distribute electricity, as they do gas and water, throughout our houses, so as to furnish great cities with cheap, pure and abundant light. "'Tis a consummation devoutly to be wished." Now, I am one of those who do not believe in the word "impossible," but I say, that with our present knowledge, this problem is insoluble. There are those who don't say so, but who think I am an obstructive lunatic. But what are the facts? Numbers, thoughts, words, can be manipulated anyhow—hence Whig and Tory, High Church and Low Church, *et hoc genus omne*, but facts are inexorable. Sir William Armstrong can only keep 37 lights going; Lane Fox could only show 12 lights; Professor Adams could only produce from the most powerful dynamo-machine, by calculation, 140 lamps. Where is the subdivision? The advocates of subdivision assume an exhaustible source of electricity. Their opponents reply that there is but a very limited source of energy in every dynamo-machine. Subdivision means loss of

power, waste of energy, and useless expenditure. We are not all Sir William Armstrongs, who can say of his brook, "I can afford to waste that which costs me nothing." One ardent disciple of subdivision says: "There is practically no loss in dividing the electric light produced by this means (by incandescence)." Now, is the production of 925 candles when you ought to have 6,000, no loss? Is the production of 3,600 candles on the Thames embankment, where you ought to have 25,000, no loss? Our dynamo-machines have their limit, and no power on earth, either of subdivision or of multiplication, can make the machine do more than a given amount of work. It may be that in course of time, and, probably, very soon, too, more powerful machines and lamps of lower re sistance, may enable us to light up a greater number on one circuit, but this is not subdivision, it is multiplication. I anticipate more advantages from the transmission of power, and I look forward to the day when I shall have in my own house a small and simple dynamo-machine, working my own lamps, and no one else's. I have not the slightest ambition to be dependent on electric currents generated miles away, and liable to all the interruptions to which I, as a telegraph engineer, have had long and painful experience.

Now, having got our light, the next question is, how can we utilize it? This question, as far as external illumination is concerned, is about to be solved for us in a very interesting way by the city authorities. We have, first, the centralized system of Dr. Siemens, where one machine works one powerful light, raised like a small moon upon the top of a high mast; and we have, secondly, the distributed system of the Brush Company, who utilize the existing street lamp posts, one machine working many lights. I have no doubt myself, from my own observations, that for symmetrical spaces, large areas, such as docks, parades, squares, &c., the former is the best; but for long and narrow streets and thoroughfares, the latter will prove superior.

The same arguments apply for internal illumination. Nothing can be more perfect than the centralized system at the British Museum, while the distributed system would alone meet the case of such a place as the Waterloo railway station. For the former we want height and space; for the latter length and lowness. In fact, the longer and lower the place to be illuminated, the less is the intensity of the light required; and when we come to long rooms and passages, we possess all we require in the small incandescent lamps. It is not difficult to show that such conditions may arise, even in external illumination, that a few small lamps, well distributed, will illuminate better than one or two powerful ones.

An eventful feature in practical lighting is the proper scattering or diffusion of light, by shades, screens, and reflecting surfaces. There is an archway at Waterloo station that is wonderfully lighted, owing to the white glazed tiles on its sides, forming such admirably reflecting surfaces. We want to emulate the diffusion of daylight. It is marvelous how whitewashed surfaces do this. Well-selected globes act as though they were self-luminous — they scatter light and prevent shadows.

The reason why daylight is so diffused, and the light searches out the inmost corner of our cupboards and our drawers, is simply that practically the whole sky becomes the source of illumination, light radiating from each point. One interesting question that will be solved by the great experiment commencing to-morrow in the city, will be the relative efficiency of different lights in penetrating fogs. It is a point open to the observation of every one of us, that the electric light upon the Thames embankment exhibits no more power in penetrating fogs than gaslight. The reason of this is extremely simple. Light, as I have previously explained, is due to the undulation of matter. There are waves and waves; some like the mighty ocean swell, tossing the "Great Eastern" like a cork in a basin; others are reflected from the side of the cork, as the billows of a storm are tossed back by a solid pier. The color of the sky is due to the reflection of the tiny blue waves, by excessively minute material particles floating about. The red sky at night is due to the unimpeded transmission of the larger red waves, the smaller ones being checked; hence the dull red of the

round sun in a mist, and the destruction of the smaller rays of the electric light, which lend it that bright and brilliant violet tint in clear weather. For the same reason that the penetration of the electric light is no greater than gas, its illuminating power in its immediate neighborhood is more. For these small rays which had been checked by material particles from penetration are reflected back to the immediate neighborhood of the light. There is a great difference between the quantity and the intensity of light. There may be a light of very low intensity, but yet of such large quantity as to penetrate to a considerable distance. A ship on fire at sea, for instance, is seen to an enormous distance; and it must not be forgotten that the law of squares, by which the relative intensity of light is determined, is true only for points; it is not true for surfaces. A large flame of gas, though its intensity is so much less, may be as luminant as a point of electric light. Beacon fires, though of very low intensity, are visible very far. In fact, if we increase the luminous area as we recede from it in proper ratio, we shall maintain the same amount of illumination; hence the great failure of photometric measurements to which I have alluded. A photometer measures the intensity of light, not its quantity.

It is important to acquire some experience from the actual users of the electric light, and to know what amount of business has already been done. For instance, there are nearly 300 Gramme machines in use in England generating light. There are many more Siemens', while the Brush people have already installed many machines and lights.

The Trinity-house, who have applied the electric light to lighthouse purposes, have at present confined its use to Souter Point, South Foreland, and the Lizard. They find that the expense involved in the installation of the light is very considerable, and it cannot be adopted without very strong and powerful reasons. Perhaps the greatest extension in the use of the light has been for naval purposes. Nearly all our present ironclads are supplied with the electric light. The last addition to this list, the "Inflexible," will have no less than two Brush machines, each producing sixteen lights. These machines will be arranged to work together or separately. There will be lamps in the citadel, in the engine and boiler-rooms, in the steering platform, below the torpedo department, in the magazine and shell-rooms; they will be used for buoy lights and masthead lights, and probably, as there will be plenty of accommodation on board for the production of electricity, the cabins will be lighted with some incandescent lamps. The "Minotaur," again, is fitted with sixteen Brush lamps; and, in fact, for torpedo purposes, the light is not only useful, but absolutely essential. Last year I had the pleasure of spending some time in the Mediterranean on board a ship laying a submarine cable between Marseilles and Algiers. Our operations were carried on by night as comfortably as by day, by the aid of the electric light.

Libraries, again, have become a useful field. Reading by gaslight is irksome; reading by the electric light is simply delightful. The Picton Gallery at Liverpool has been so lit for a long time, and the British Museum is now permanently illuminated by five arc lights, which fully answer the purpose. This has enabled the authorities to keep the reading room open daily through the winter till seven o'clock, and only on one day (and that within a short time of the hour of closing) have the lamps failed, the failure being due to a want of proper fuel for the engines. At South Kensington 32 Brush lights are used with great success, and afford every satisfaction, not only as a luminant, but in an economical sense.

Railway stations are gradually adopting the lights. The Liverpool-street Station of the Great Eastern, the Paddington Station of the Great Western, the Waterloo-bridge Station of the London and South Western, the Charing-cross Station of the South Eastern, the Bricklayer's Arms (Goods) Station of the South Eastern, are being practically and effectively lit, and the St. Enoch's and Queen-street Stations at Glasgow, as well as the Victoria Station at Manchester, are equally successfully being lit.

Again, we find seaside resorts availing themselves of it for the illumination of their parades. Blackpool, for instance,

has, with great enterprise, lit up the whole of its parade and piers with great success.

The new Albert Docks on the Thames, the Alexandra Dock at Newport, the Mersey Docks at Liverpool, are all spreading the use of this light with considerable speed. I was surprised last year to find the Belle Vue Gardens at Manchester (a pleasure resort that reminded me very much of the old Surrey Gardens we used to have in London) where, without any expert assistance, the active managers, the Brothers Jennison, had rigged up several lights themselves, and had experienced neither trouble nor difficulty in the matter.

It would be impossible to make any summary of the numerous works, mills, dye works, &c., that have been supplied with lights worked successfully. The Iron works at Barrow, for instance, have very extensively employed it; while the *Times* office was probably the first place in London to inaugurate the introduction of the electric light for such purposes. Shops and warehouses in all parts of the country are now being lit up—Whiteley's, Shoolbred's, Nicholl's, Regent street, Crocker's warehouses in Friday street, and many other places, and now we find the city inaugurating the illumination of their streets and open spaces. I never pass that wretched excrescence that indicates the site of old Temple Bar, without wishing that the heraldic beast that surmounts it were removed, and supplanted by a handsome bronze pillar 30 or 40 feet high carrying a miniature sun. It would not only make the memorial more ornamental, but it would make it useful as well.

One of the most useful purposes to which the light has been applied, is that of photography. Not only are pictures taken by its aid in the wretched fogs of winter, that quite destroy the actinic power of sun rays, but it is used to a very large extent in carrying out what is known as the Woodbury process. The electric light is not so powerful as sunlight, *i. e.*, it does not operate with the same rapidity. Electric light takes, in fact, three times as long to print gelatine reliefs for the Woodbury process, as the sun; but Messrs. Lock & Whitfield assure me that they hardly know what they should have done during the past sunless winter without its aid. Whether the exposure is for one hour in the sun, or three hours in the electric light, is a matter of no consequence, if the quality of the results are similar; the sun, however, has an advantage, due, doubtless, to the greater quantity of light that it emits.

Perhaps, however, the most interesting appliance from a scientific rather than a commercial point of view, is the application, by our worthy chairman, of this light to horticultural purposes. He has found that it fulfills all the requirements for the growth of plants and ripening of fruits; and he has at his country seat, near Tunbridge Wells, carried on a very large series of experiments, that have created quite a sensation in the scientific world.

Notwithstanding these great advances in its use, it must not be forgotten that the electric light has its defects and its disadvantages. All is not gold that glitters. The intense shadows that it emits are troublesome. The unsteadiness of the light is at times wearisome. The hissing that impurities in the carbon and irregularities in the current produce is tantalizing, and the light has an unfortunate habit of misbehaving itself when it is most wanted. Moreover, the problem of durability remains yet to be solved. Many have tried it and abandoned it. In some cases its economy is unquestionable; but there are places where careful persons have shown that gas, as regards economy, surpasses it. It is questionable whether, in some cases, the electric light does not affect the eye. The experience, however, of the readers of the British Museum, is entirely in its favor. Nevertheless, I have myself suffered much from the light; true it was in experimentation, and the same thing might have happened with any intense light; but rumors do exist that eyes have been affected, and probably sufficient time has not yet elapsed to solve this question. The arc light produces, also, nitrous acid and other deleterious gases, as is shown in the condition of the lamps. The incandescent lamp, is, however, free from this trouble. The powerful currents that it requires cannot be carried over buildings and rooms without incurring danger from fire and to life. It has been proposed to utilize

the electric light in coal mines, but, to my mind, one might as well lay a train of gunpowder along a mine gallery, if it be at all a dangerous one, as a wire conveying such powerful currents of electricity as a light needs, unless that wire be most carefully protected.

The disturbance due to induction I have already alluded to. Nevertheless, in spite of all these defects, the light has great and manifold advantages. The brilliancy of a well-lit room is simply enchanting. The purity of the light for the transaction of business, the selection of colors, and the ordinary daily avocations of life, is simply superb. The cleanliness of the light is one of its great merits. It emits no smoke; but probably its greatest advantage is to be found in the influence it exerts on health. We all know that the air is vitiated to a certain extent, by the mixture of carbonic acid with it, and it has been well shown that to be consistent with health there should be not more than six volumes of carbonic acid in ten thousand volumes of air. When the proportion reaches ten volumes to ten thousand, the action of the heart is affected. When this proportion runs up to from fifteen to thirty volumes in ten thousand, headaches occur, and in higher proportions, rheumatism and bronchitis are the consequences. Now, five thousand cubic feet of fresh air per hour per gas burner, consuming three feet per hour, are required to maintain your health; in fact, in our great galleries at the General Post-office, we require two to three million feet of fresh air per hour to provide a healthy atmosphere. The electric light sweeps away all the necessity for this ventilation. It does not vitiate the air. We have found at Glasgow, where we have applied the electric light, that all these causes of trouble have ceased. Health has been engendered, more work has been got out of men, and, in point of fact, the experience of others shows that the electric light will pay for itself even in the increased work that can be obtained out of labor in consequence of its use. Not only is the health of the subject improved, but men are able to do more work in a given time from the influence of this pure light than from the impure light of gas. We still want brilliancy combined with steadiness and durability. The advances made have not been so much in this direction, as in the improvement of details, and in a greater knowledge of electrical measurements and of the relations that exist between electricity, heat, and light. Electricity as a substitute for gas is not a delusion; it is practicable. It supplies a real want; but for domestic purposes it is at present a luxury, and an expensive one. Predictions as to its grand future have not yet been fulfilled. The public have shown themselves remarkably sensitive to its influence on gas. Nevertheless, it has a bright future before it, and, though the poet might have said:

> "It was a phantom of delight,
> When first it beamed upon my sight;
> A lovely apparition sent
> To be a moment's ornament."

if he had lived in the present day, he would have considerably added to the period in which he estimated the electric light to be an ornament.

ILLUSORY SANITATION.

From "The Building News."

Since the institution of local and other Boards charged with the duty of protecting us from the dangers consequent on an improved system of sewerage, ills before unthought of have unpleasantly developed themselves, creating dismay instead of hoped-for comfort and contentment. In the gradual and unavoidable transfer of our personal control of the evils of the house to those endowed with popular as well as legal authority, we lost our individuality, and while contributing to the costs of such machinery became mere helpless units in the force by which it is impelled and governed. Ever since drains and their controlment budded into a science, many a theorist has had ample opportunity of airing his opinions, but in the course of the numerous tentative blunderings, much evil and

discomfort has been inflicted. To add to what in itself was trying enough, *progress* developed new types of disease hitherto unknown, and the disturbed and conflicting views of our medical authorities added substantially to the dangers of the situation. Hence, like in other matters of a domestic character, an unsettled feeling of distrust has arisen, leading the afflicted—we might even say the oppressed—to grasp at any seeming chance of relief from the uncomfortable and dangerous character of their unsanitary surroundings. Modern unsanitaries, when dissociated from the complex and bewildering phrases which engineering and medical scientists have surrounded it, is a very simple question indeed, for it only really means that the dwelling and its inhabitants have become endangered by a neglect of the most ordinary health-preserving precautions. Whether these dangers are self sought or vicariously inflicted, does not very materially affect the question, for their existence, under any circumstances, necessitates the most serious attention to their remedy or removal. We may take it, however, that much discord and disagreement prevails amongst those professing to have special knowledge of what is now generally accepted as sanitary science and its complex teachings.

These considerations readily occur to us at the present time from the recent organization of a sanitary insurance society, launched under doubtless creditable auspices, and framed on the model of a similar institution, believed to be doing good and honest service in the metropolis of Scotland. All things must have a beginning, and it is a healthful sign of progress in any direction, when it is founded on a basis practicable and trustworthy in character. Such, we may fairly assume, the parent Sanitary Insurance Society of Edinburgh to be; but, before accepting its teachings or implicitly pinning our faith to its guidance for dealing with a great city like London, we need not be blamed for examining the relative surroundings of the two cities, and considering whether what is good for Edinburgh is equally good for the Metropolis.

Edinburgh is favorably circumstanced as to site which, from a geological point of view, is unexceptionable in facilitating, by the peculiarly favorable character of the rock on which it is built, a ready deliverance of its rainfall and sewage to the conveniently near sea outlet at Portobello. The solid and substantial character of the buildings, and wide and well-conditioned streets of the Modern Athens, are also good and useful factors in securing a tolerably fair state of sanitary comfort. We refer generally to the newer portions of the city, for the Canongate and other similarly circumstanced ancient localities are not by any means perfect in their sanitary surroundings. The city of Edinburgh also, has another and special advantage from its having been the first large community which derived any benefit from the utilization of its sewage, as the long continued fertility of a portion of the Portobello sands testify.

A city so circumstanced and occupied by a comparatively limited high-class population, offers peculiar facilities for the successful treatment of its sewage, due, primarily, to the precipitous character of its site securing a high velocity for its passage to a good and contiguous sea outfall. There are few, if any cities, which command similar advantages, and under intelligent control, sewer gas, as understood in London, need not have any existence in Edinburgh at all. Constructive science generally is in a much better condition, the quality and character of the masonry being better than work for similar purposes in London; for, in the northern city, the "jerry builder" has not yet, nor is he likely to obtain a footing equal in importance to that which he commands in London.

We have thus glanced at the conditions which, by their exceptionally favorable influence on the sanitary state of Edinburgh, and which are being offered as the model, whereby a protection society is to be established for the well-being of the inhabitants of London. Under any circumstances, the difference in extent between the two cities would interpose difficulties in the way of establishing sound and healthy sanitary control and government, let alone the almost insuperable obstacles, the inheritance of governmental supineness and constructive defects. Like unto many other great

cities of ancient as well as modern times, London is placed upon the banks of a tidal river which, until very recent times, received all its drainage, and sometimes worse, of whatever kind which its inhabitants could not otherwise dispose of. It was not until the abandonment of cesspools and the introduction of larger supplies and use of water that any evil effects were recognized in the use of the Thames as the main scavenger, to whose care was entrusted the waste of London's citizens. When, however, increasing population, and a better appreciation of what may be termed "personal cleanliness" developed to an alarming extent, the river was no longer competent to accept its ancient office without rendering its waters so impure as to create a nuisance which, during certain seasons, almost prohibited its use for pleasure purposes. The malodorous stream, therefore, in all its nastiness on one hand, and the congestion of inland sewage on the other, ultimately resulted in the organization of a powerful body invested with popular authority to undertake the government and control of the main or arterial drainage of London. The area apportioned for the exercise of the Metropolitan Board of Works' rights and authority was limited and prescribed in character, embracing, however, all the parishes proper of the city and suburbs. The physical conditions, however, of the space to be dealt with, were much more unfavorable than those at Edinburgh, neither was the authority so concentrated or effective in its capacity of control. The interception of the drainage of all kinds, was the first condition on which the Board purposed to base their ultimate operations, and accordingly the main sewers were designed to receive and convey to outfalls the whole filth of London and its affiliated parishes. The natural fall of the river Thames in its circuitous course was not very considerable, and as the selected points of outfall were on its banks, any improved gradients of the drains were only possible by reduced length and depressed reservoirs of discharge. The conditions, therefore, controlling the scheme of London drainage are very different, and much more onerous than those existing at Edinburgh, or, indeed, anywhere else in this country. Simple collection and controlment of the accumulated sewage produced from a population of something like 4,000,000 of people, is not, by any means, an easy task, but to provide for its removal or extinguishment is even more difficult. We shall endeavor to describe the machinery by which this task is accomplished.

Tidal influences prevent the free and continuous discharge of the accumulated sewage, and it is therefore desirable only to pump out the contents of the north and south reservoirs at flood tide, or practically twice during every twenty-four hours. The obvious reason for this arrangement is that, theoretically at least, the receding tide conveys the sewage and its associated belongings to distant points which are not supposed to be prejudiced by its deposit, for, according to all natural laws, its total extinguishment is impossible.

Such, then, under normal conditions, is the position of the London main drainage, as now controlled, and to the government of which all other subsidiary drainage is amenable or subordinate. The householder, however desirous he may be of rendering his home proof against the insidious influence of sewer gas, cannot control the insuperable defects inherent in the very inception, execution, and government of the main drain proper itself. He is bound to connect his house, and to pour into the main channel all and every iota of excreta, &c., produced by him and his surroundings into a noisome stream, which already contains, according to the position in which it is emptied, the outpourings of hospitals and divers populations. It is this kind of unavoidable bondage which creates one of the most dangerous difficulties of the sewerage system, for it complicates and intensifies the dangers of the ordinary householder. To clear his house of what, under the modern system of cleansing is regarded as a dangerous common nuisance, he becomes intimately associated with the almost illimitable, and certainly indefinable accumulated refuse of, it may be, millions of his fellow subjects, who, in the universal thraldom of main drainage slavery are helplessly compelled to submit to the lot apportioned them by the controlling authorities. The cleansing of the river Thames by the interception of the Lon-

don sewage, not only overcame the crying evil of a polluted stream, but it promised comfort to the luxurious inhabitants of a great city, who disregarded the evils likely to follow from such a system when it apparently secured present immunity from the dangers and annoyances of a complex system of cesspools and imperfect drains.

The new dispensation, however, in its complicated surroundings begets evils hitherto unknown, and it is from such dangers that the modern sanitary engineer and scientist promises relief and safety. The main sewer traverses in its tortuous course all sorts of conditions of localities and neighborhoods, and becomes charged with the most heterogeneous contributions from pure as well as polluted sources. Under such circumstances, therefore, the huge and, in constructive sense, substantial sewer conduit becomes a retort for the production of gaseous products, which, from uncontrollable natural laws ascend, finding vent in the weak points of the concomitant subsidiary drains, thus insidiously entering the dwelling, thus engendering disease, and inducing death. From the extreme west to the distant east of the huge aggregation of streets and dwellings of London, and its affiliated suburbs, the slow wending stream of pollution drags its slow course along, receiving from various tidal and other influences, checks to its onward progress towards the point of its ultimate river discharge. Conserved for a brief and naturally defined space of time in the huge reservoirs, it is emptied by mechanical agency on the full tide, which theoretically is supposed to float it seawards, thus securing its removal beyond further baneful influences. This question of removal is of great and paramount importance, which, in the future, will receive some sensible solution, for at present there is much diversity of opinion as to the efficacy of existing means of sewerage disposal. A but recent alarm in the Firth of Clyde, on the banks of one of its numerous and beautiful lochs, seems to show that sewage matter, however carefully dealt with is the source of ultimate danger at the seat of its disposal. The dredged mud from the malodorous Clyde, into which Glasgow empties its sewage and other abominations, is by means of hopper barges deposited in a deep loch upwards of 25 miles distant from that city. Careful medical examination, influenced by the appearance of new types of disease, proves that they are engendered by the deposit of Glasgow sewage mud, which gradually, even from the depths of its deposition, forms, on the shores of a beautiful loch, posonous matter, which converts one of the healthiest seaside resorts into a pestilential fever center.

London, in like manner, although, by somewhat different means, is freed from its filth; but unlike Glasgow, its population suffers during the process of collection and storage from the poisonous sewer gases which its accumulation unavoidably occasions.

The difficulty, therefore, in contending with sanitary improvements in London is much greater than any other city, because the length and capacity of its main drains create and store up poisonous matter, difficult of controlment, or even elimination. Under certain conditions, indeed, such as those created by heavy rainfalls and floods, an hermetically-sealed house-drain connections would be almost incompetent to withstand or resist the pressure of the pent-up gases of many miles of main drain. There is no present possibility of increasing the velocity of these sluggishly-driven sewage streams, and therefore the sanitary expert, in setting about his task of remedy, must first deal with an evil over which he can exercise no appreciable control. He must fight the demon of disease by remedial rather than by preventive means, and the Herculean task of effectively rendering a sewage-connected London dwelling proof against the entrance of gases is one of difficult performance. Even if the surroundings of the case were in themselves simple and easy, the perfect isolation of a house from its associated sewer, if not practically impossible, is one of more than ordinary difficulty.

Examine the character and quality of the subsidiary sewers of London, with their faulty lines and gradients, and bad materials imperfectly connected with the houses along their course. Houses hurriedly and badly built on yielding foundations cannot be effectively or permently sewered, and disjointed pipes readily afford the means of sewage saturation in

foundation basements, if not in the upper walls, of a large proportion of the "jerry built" dwellings of a London suburb. The house so circumstanced may be for a time regarded as less liable to the entrance of sewer gas, because its virulence is absorbed in the soil and porous materials of which it is constructed, although in the long run it must essentially become a "diseased house."

There are, unfortunately for the London householder, none of the favorable conditions attached to his case which secure for the citizen of Edinburgh the advantages of a Sanitary Protection Society; and which, in the interest of public safety, has been extended to the metropolitan house dweller. There are obstacles of a formidable nature to be encountered; not the least of which consists in the fragile structural character of the house itself, which would, in too many cases, be incompetent to withstand the disturbing influence of the necessary works to ensure its sanitary perfection. The machinery of remedy offered by the new Sanitary Society, is quite voluntary, and may, we trust, exert some beneficial influence in dealing with favorably-circumstanced cases of an exceptional character. We are not hopeful, however, of seeing much improvement realized by its exertions, for the evil is too deep rooted for private enterprise to overcome or remedy. In the direction of guaranteeing sanitary perfection in newly-built houses there would be better prospects of success, for a dwelling so circumstanced would secure a rental higher even than the extra cost required for its invulnerability against disease.

In the absence of sufficient controlling authority London is allowed to extend itself in all directions, by the building of new houses, many of which, under proper challenge, would not be allowed to be built. There is a lamentable want of accord all round on this vital question, notwithstanding the abundance of remedial authorities, which would have but little employment or attention bestowed upon them, if the necessary primary measures of prevention were fairly considered and insisted upon.

Apart from what may be termed foreign or external danger, produced by the causes we have referred to, there are domestic and internal sources of diseases built with the house, and, like the ailments of a helpless child, inheriting parental taints, may be regarded as practically incurable. Walls (placed on manure-charged soil) composed of bricks, competent to absorb in many cases their own weight of moisture, and jointed with mortar produced from road sweepings and sometimes worse; timber, which if not primarily defective, speedily from its position becomes rotten, and walls plastered with porous and spongy materials, which have their surfaces covered with poisonous papers stuck on with vegetable paste, which soon engenders a fungus growth capable of destructive and malignant influences; the carpets, curtains, and indeed, every item of furniture of such a house, and the clothing of its inhabitants, are, in themselves, calculated to create disease, without the supplemental danger of sewer gas. Absence of ventilating appliances intensifies the dangers arising from the conjuction of so many formidable and, under the circumstances, uncontrollable evils. The windows and doors are *fortunately* not capable of being hermetically closed, which should be regarded as a signal advantage, for it permits of some degree of relief, by the entrance of air in and through this dwelling of undoubtedly "shoddy" surroundings.

London and its doings is looked upon by provincial cities and towns as a model for imitation, and in the matter of drainage we fear the lesson has been read too slavishly, leading to the general adoption of sewage disposal into sea or river outlets. What has been done in the Metropolis is considered a guide as to what should be done elsewhere, and so main drains, and wasteful and dangerous water outfalls, have become fashionable. Look, say the servile imitators of a vicious system, at the main drainage of London: it cost millions, and conveys away, in the most perfect manner, all the waste of so great a city. The bill for all this supposed comfort has not yet been settled, for suffering, disease, and death are still sending in their ever-recurring claims, which must be met, and while they continue to be presented, they record the incontrovertible fact that the source of their origin is due to a lamentable infringement and disregard of nature's laws.

ADDITIONAL WIDTH OF GAUGE ON RAILWAY CURVES.

By THOMAS DOANE.

A Paper read before the Boston Society of Civil Engineers.

Some two or three years ago, an inquiry was made as to making the gauge of railroad tracks wider upon curves than upon straight lines. The editor asked for information upon that subject, but, so far as I know, the matter has had no further attention, though it is a *very important* one.

As long ago as 1870, in laying track, I widened the gauge upon curves, but having turned over the road to the operating department upon its completion, I had no opportunity to further study the experiment, and have therefore remained silent.

During a recent visit to the road referred to, I learned something further about it, which may, perhaps, be interesting to the members of our Society; certainly to those who have to do with railroads.

The experiment alluded to above was made upon the Burlington and Missouri River Railroad, in Nebraska.

Previous observation had shown me that, though the tracks upon the straight lines and upon the curves had been originally laid to the same gauge, the gauge upon the curves was soon widened out by use. I do not now remember whether my observation showed a movement of but one, or of both rails, but I concluded that the widening of the gauge was due to the *stiffness of our trucks*, and their failure fully to traverse upon the curves, and *not* to centrifugal motion. If this were the fact, it would even then be probable that the exterior rail of the curve would suffer the greater movement. Simple stiffness of trucks would be likely to affect both rails equally, but adding to this influence that of centrifugal force, unless it be *fully* counteracted by difference of elevation, and the exterior rail would show the greater displacement.

This condition of things showed a *want* of *fitness* between the track and the rolling stock, and a consequent unnecessary, if avoidable, wear and tear upon both, and a waste of motive power.

It seemed to me that if the moving trains were *bound to take more room* between the rails, that it would be better to *give* it to them *at the first*. Then the rails would be firmly seated and remain in their places. If this is not done, and the rails are laid to *straight line*, or *close gauge*, then the heads of the rails will be forced apart, the rails will be tipped on to their outer edges, either cutting into the ties or pulling their interior spikes, or both, thus loosening and disjointing the whole *permanent* way. So long as the gauge remains too narrow for the trains, there must result from the friction between the wheel flanges and the rails great wear and destruction of both.

If the gauge of curves be made open and loose, the *coning* of wheels will be utilized.

And, further, an engine will haul a larger load than if the train is pinched between rails too closely laid.

And, what is perhaps of more importance than anything else, *greater safety* is secured upon a track with an *open gauge*, in which the rails are firmly secured in the places where they are to remain, than upon a loosened and deformed track.

Upon the main line of the Nebraska road, the curve of greatest radius is a 30′ curve, and of least radius a 3° 30′ curve. In laying tracks on *all curves* of *less* than 2° the gauge was increased from straight line gauge $\frac{1}{4}$ *inch*, or to 4 feet $8\frac{3}{4}$ inches, and 2° curves add over were laid to a gauge of 4 feet 9 inches, being an increase of $\frac{1}{2}$ *an inch* over straight line gauge. *Three* sets of gauges were furnished the section men, of the lengths stated above for the curves, with the usual straight line gauge of 4 feet $8\frac{1}{2}$ inches, and the men were held to the use of them, until the road was turned over to the operating department by the engineering and constructing department.

At that time a new road-master came in, who either did not understand, or did

not appreciate what had been done by his predecessors, and curved track was gradually brought to the straight line gauge of 4 feet 8½ inches.

Since this road-master left, the tracks upon the curves, while undergoing repairs, have been restored to their original gauges, and have so remained now for several years. The man now in charge says that the practice gives great satisfaction; that the tracks upon the curves are maintained in *good condition*, at very little expense; that the *wear* of rails is sensibly diminished; that the engines can haul a *maximum* load, and that *no accidents* have occurred from increasing the gauge.

I have been told that, on hearing of laying track with open gauge upon curves, the officers of the Atcheson, Topeka, and Santa Fé Railroad adopted the plan for their road.

As there was but one curve on the Nebraska road of shorter radius than that of a 3° curve, no attempts were made to widen gauge, more than the ½ inch alluded to. I have no doubt, however, that it would be entirely safe and wise to widen to the extent of one inch, or slightly more. The tread of our railroad car wheels is sufficient to prevent the wheel from dropping from the rail even then, and if laid 1½ inches open, the tread of the wheel, as now made, would cover about all of the tread of the rail.

Since writing the above I have had occasion to refer to the matter of resistance of curves to trains; and in an article by Baron Von Weber I find the subject of *widening gauge* on curves *incidentally* alluded to. I was therefore mistaken in saying that the matter had no further attention since the inquiry of the *Gazette* had been made, but as it did not appear under a head distinctly bringing the *subject* to notice, it may have escaped the eye of the original inquirer, as it did mine.

The experiments of Von Weber were made in 1876–7–8, and his article entitled "Train Resistance on Curves" appeared in the *Railroad Gazette* of June 11, 1880.

Item No. 9 of a summary of the above is as follows: A reduction of the additional width of gauge on curves customary on the Bavarian roads, one half or more, contrary to expectation, caused an increase in the resistance. The additional width given on these roads is:

Radius of meters.	Radius in feet.	Degree of curve	Additional width of gauge in meters.	Additional width of gauge in inches.
750 M	2482 ft.	2° 18′	0.008 M.	0.32 inch.
550 "	1822 "	3° 9′	0.014 "	0.56 "
400 "	1320 "	4° 20′	0.020 "	0.80 "
300 "	993 "	5° 45′	0.025 "	1.00 "

This result, however, cannot as yet be considered as fully established. This is the end of the quotation.

It would seem, then, that the widening of curve gauge upon the railroads of Bavaria is now usual, but how far back the custom extends is not shown by Von Weber's article.

It appears from the experiments that the *reducing* of the *additional width* of gauge increased the resistance to the passage of trains. The converse would therefore be true, within certain limits, that an additional width of gauge would decrease the resistance. This is in accordance with my own theory and experience, and it is to be hoped engineers will give the matter further attention and experiment.

The gauge of the tracks of Bavarian railroads is not given in Von Weber's article; but presuming it to be not very different from the standard American of 4.71 feet, there seems to be a very close agreement between the additional widenings which I gave the curves of different degrees in 1870, and those which are now used on the Bavarian railroads.

If I had been living in a country, or at a time, when engineers were expected to think and work in *metrical terms*, there *might* have been a still closer agreement.

REPORTS OF ENGINEERING SOCIETIES.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS.—The last issue of "Transactions" contains paper No. 217, "On the Ventilation of Halls of Audience," by Robert Briggs.

At the meeting of the 4th of May, held at the new quarters of the Society, a paper on "Quicksand in Excavation" was read by Charles L. Mc Alpine.

ENGINEERS' CLUB OF PHILADELPHIA.—The last number of "Proceedings" contains papers as follows:

No. 7. "The Panama Canal and Isthmus," by Col. James Worrall.

No. 8. "The Strength of Wrought-Iron Columns," by Thomas M. Cleeman.

No. 9. "Progress of the Second Geological Survey of Pennsylvania," by Charles A. Ashburner.

No. 10. "Intercommunications in Cities," by Prof. L. M. Haupt.

At the meeting of May 7th, Mr. Rudolph Herring gave a general account of a recent examination of the sewerage systems of European cities.

ENGINEERING NOTES.

THOUGH it is impossible that a Channel tunnel railway can ever pay, unless some genius in railway management arises to show how trains can be made to follow through the tunnel at more frequent intervals than they do at present on the Metropolitan Railway, and also to persuade more millions of passengers to travel between England and France than now travel on the great London underground system, the South-Eastern Railway Company is still spending money boring in into the chalk near Abbot's Cliff. Already it is stated that a 7 foot heading of 300 yards on a sharp gradient has been cut by one of Brunton and Trier's boring machines made on the principle of their stone dressers, and Colonel Beaumont, R. E., is busy on the work. A small steam pump is sufficient at present to keep the water under, but the heading is yet only at about low water tide level, and doubts of the entire freedom from shakes or fissures of large size in the chalk are not altogether absent. Does Sir E. Watkin think he is going to frighten the shareholders in the London, Chatham, and Dover by this costly little experiment?

RAILWAY NOTES.

MOUNTAIN RAILWAYS.—The *Génie civil*, a new French publication, to the recent appearance of which we lately referred, has in one of its earlier numbers a description of an improved system of mountain railways entirely original in its conception. It is well known that the construction, maintenance, and working of mountain railways have long occupied the attention of engineers. Many methods of climbing steep inclines and of rounding curves of small radius have been proposed, and several of these methods have been reduced to actual practice. The systems of Fell and Riggenbach are very well known, and the ancient system of rope tramways is in use in many places. A French engineer, M. L. Edoux, has conceived a project which is based upon the application of a system of hydraulic elevators to the lifting of cars to any height. This system may be applied to great advantage when an abundance of water under high pressure is available. These conditions will be frequently met in a mountainous country. Although this project has not yet been realized, it seems to possess sufficient merit and novelty to render it interesting to our readers.

The particular railway under consideration is intended to establish communication between Cauterets and the baths of La Raillère, in France. Cauterets is situated in a narrow valley, at an elevation of more than 2800 feet. It is a noted watering-place, and during the season is filled with numbers of invalids, who go there in search of health. The hot sulphur springs, for which this region is noted, are located at La Raillère, 400 feet higher up the mountain, and nearly a mile distant by road. To travel over this fatiguing route, to go and return, often twice in the same day, in the capricious weather of the mountains, and in the crowded omnibuses, is uncomfortable and even dangerous for infirm persons. The waters cannot be conveyed from La Raillère to Cauterets without modifying their temperature and their chemical composition, to which their therapeutic properties are due. It is therefore necessary to convey the sick to the springs that they may receive the full benefit of the waters. This railway has been projected for the purpose of conveying the bathers from Cauterets to La Raillère rapidly and comfortably. All systems, with the exception of that of M. Edoux, require the consumption of a large amount of fuel, which in this region is very expensive. This inventor utilizes the powerful waterfall at La Raillère, which, in connection with gravity, constitutes the motive power of the railway.

The proposed mode of working the railway is as follows: The car is raised vertically by means of hydraulic elevators to a greater height than its destination, which, in the present case, is La Raillère, and is then allowed to descend as far as that place by its own gravity upon an inclined railway. To return, the car is transferred by its own gravity to a second railway inclined in the opposite direction. The cars are provided with efficient brakes, by means of which the speed may be effectually controlled. In practice, the car is not raised the vertical distance 400 feet at a single lift, but this distance is divided into five parts of 80 feet each. There are five towers at intervals of about 130 feet. In each one it is proposed to place an hydraulic elevator, similar to those introduced by M. Edoux into the hotels and houses of Paris. The top of each tower is a little more elevated than the foot of the next one, and is connected with it by an inclined bridge. The car is raised by the hydraulic elevator to the top of the first tower, runs by its own gravity to the base of the following one, is raised to the next level, and so on. Together they form a gigantic staircase, with steps 80 feet high. The last landing place is 420 feet above Cauterets. The return way, which is on the side of the mountain, terminates in the second tower. The cars descend vertically only in the first two towers, which contain two compartments, one for hoisting the car and one for lowering it. At La Raillère the inclination of the car is reversed, and the car is transferred to the return track by means of a platform supported

on wheels and provided with rails. The car on arriving from Cauterets rolls upon the platform. The latter moves by its own gravity on rails slightly inclined in opposite directions, so that, when the rails of the platform join the return track, their inclination will have been reversed, and the car will, of its own gravity, return to the second tower. The movement of the transferring car is controlled by an hydraulic piston. The gradient of the railway is very slight, just enough to supply an impetus.

OBSERVATIONS on the part of different railway men do not agree as to the relation between season and the breakage of rails. In a recent issue of the *Organ fur die Fortschritte des Eisenbahnwesens*, Herr Theune states the results of his observations with respect to the fractures of steel rails in the district—Kattowitz—under his observation. He notes that 329 such fractures took place during the years in which his interesting observations were made. Among the rails which were laid in the open country there were 2.4 fractures per mile, while in forests, where rails are exposed to greater damp, the rate rose to 6.7 per mile. The changes of the various seasons have a striking influence on the number of breakages which take place. Thus, during the first quarter of the year—the coldest season generally—there were 216, in the second quarter 28, in the third quarter 14, and during the fourth quarter 71 fractures. The greatest number of fractures of rails took place from the eighth to the tenth years after their having been laid down; the average working time was found to be 7.5 years. With respect to the parts where fractures took place, Herr Theune remarks that there were 73 fractures in the face of the rail, 51 breakages in the web, and as many as 265 fractures through the fish-plate holes. The very great excess of fractures in the first quarter seems to indicate error in observation or in the accounts consulted.

IRON AND STEEL NOTES.

THE report of the North British Railway Company for the meeting on the 31st inst., shows that the company now possesses of effective stock 470 engines, 426 tenders, 297 first-class carriages, 67 second-class, 662 third-class, 178 composite, 140 horse boxes, 148 passenger luggage vans, 1 post office, and 1 meat van, 101 carriage trucks, 1 horse carriage, or 1596 in all. The effective stock in the wagon department includes 27,866 vehicles of all kinds. The total number of miles of line worked by the company's stock and engines, including those rented and worked over, is 1085½, the miles owned by the company being 870. The total train mileage in the half year ending 31st January was: passenger trains 2,278,652, and of goods and mineral trains 2,776,618. The locomotive power cost, including all expenses, £129,577 14s. 8d.

IT has been remarked in the money article of the *Times* that "there is a good deal of comment in the market on the fact of the North British Railway directors declaring a dividend on the Ordinary stock in present circumstances. A full explanation is called for as to the mode of dealing with the finance of the new Tay bridge. When the accident happened the directors wrote off £120,000 at once, partly at the expense of the Preference shareholders, about whose losses there was a great deal of outcry at the time. But if the old bridge is to be virtually condemned, even this £120,000 is not sufficient; the whole cost, which was over £300,000, ought to be written off. If a new and wider bridge is built the excess of cost to build it as compared with the cost of the old bridge may, perhaps, be fairly charged to capital; but whatever has been really lost, must be made good out of revenue. The question is of general interest in railway finance, and we trust a complete account will be given of what is going to be done, and the reasons for it."

THE Aireside Hematite Iron Company, which has introduced concrete slag as a substitute for stone, has erected new offices at its works in Hunslet, Leeds, in which all the door and window facings, and the ornamental work, are composed of the slag from its own furnaces. A new feature of such an elevation is a display of imitation carved bricks, in various colors, made of the slag, the cost of which is said to be 50 per cent. less than the real article of clay which hitherto has been so much in fashion. The Aireside Company is, we are informed, supplying the Midland and North-Eastern Railway Companies with slag concrete flags, ready prepared for use, in the laying down of platforms at railway stations. The Staveley Company has for a long time used slag lumps for building purposes, much of the slowly-cooled massive slag having the appearance of basalt and other rocks.

ORDNANCE AND NAVAL.

MACHINE GUNS AT SHOEBURYNESS.—The trials which have been carried on intermittently during the last six weeks at Shoeburyness with the Gatling, Nordenfeldt, Pratt-Whitney, Gardner, and "improved Gardner" machine guns were brought to a close on Feb. 22nd. The guns thus tried have been of two classes, the "light," for ship and boat service, and the "heavy," for service in the field. There were originally three light guns, the two-barreled Gardner, weighing 100 lbs., the five-barreled Nordenfeldt, weighing 143 lbs., and the six-barreled Gatling, weighing 200 lbs. The heavy guns were the five-barreled Gardner, weighing 302 lbs., the ten-barreled Nordenfeldt, weighing 256 lbs., the Gatling, weighing 254 lbs., and the Pratt-Whitney, weighing 261 lbs. The six-barreled Gatling was withdrawn from its failure to fire the 1000 rounds test. There were two series of penetration trials. The first series was at 20 targets an inch in thickness, placed at intervals in rear of each other, and shots were taken at these at 300 yards. The results were not entirely conclusive, as some of the shots hit nails, and so were stopped; but while one shot of

the five-barreled Gardner indented the last target but one (the 19th), others indented the 16th, while the two-barreled lodged a shot in the 14th. The Gatlings lodged shots in the 12th, 13th, 14th, 16th, and 17th, the five-barreled Nordenfeldt lodged one in the 13th, three in the 16th, and one on the 18th, the ten barreled Nordenfeldt lodging its shots between the 14th and the 16th. One Pratt-Whitney shot lodged in the 17th target, while others stayed between the 10th and 13th. The trials at the steel plates, in which the target was formed of two steel plates, "sandwiching" an inch of deal, gave the important fact that at 300 yards the bullets of most of the guns would penetrate the steel of torpedo boats. The "elevation" trials, when the guns were elevated to 30°, were taken in the shed, and the shots fell to seaward. The ammunition running short, all the barrels of the ten-barreled guns were not fired, but it was apparent that the Gatling could not feed at this degree of elevation, and the ten-barreled Nordenfeldt, though it was fed at this elevation, required manipulation, the hopper not being made to suit more than 20°. All the other guns worked successfully, and they all worked in the depression trials without hitch—these being also at 30°. The "rough usage" trials were then made, one of these being the sifting of sand above the guns. The sharp grit of the flint sand from the seashore soon penetrated to the works of the guns and stopped them one after another by choking the chambers. This was the most severe trial which the guns had. The guns were then dismounted and dragged by Royal Artillerymen in the ditches, which were full of mud. They were then handed over to the inventors, each inventor being allowed the use of a bucket of water, a brush, a screw driver, and some oil. The time was taken in which the guns could be cleaned and could fire three "feeds." The two-barreled Gardner was cleaned and had fired sixty rounds in 3 min. 32 sec. The ten-barreled Nordenfeldt was cleaned and had fired 300 rounds in 6 min. 20 sec. The five-barreled Gardner was cleaned and had worked out 150 rounds in 4 min. 21 sec., but fifty-five of the rounds passed through unfired owing to the water in the gun block not being drained off, this retarding the firing spring. The five-barrelled Nordenfeldt was cleaned and had fired 150 rounds in 3 min. 28 sec.—*Times.*

THE RUSSIAN NAVY.—The St. Petersburg correspondent of the *Times*, writing on the much controverted subject of the "Livadia," says: "The old dispute between the partisans and opponents of Vice-Admiral Popoff is not yet exhausted, nor has the Russian public heard the last of the famous turbot-fashioned yacht "Livadia," still lying useless at Ferrol. It now appears that the Russian naval authorities have set their minds upon encasing the "Livadia" in wood, as soon as her damage has been repaired and she can be got safely into the Black Sea. It is, therefore, difficult to imagine what will eventually become of this novel and ill-fated vessel, or how much more expense will have to be added to the original cost before she will be complete in the opinion of Admiral Popoff. In all probability, whatever may be the improvements made, she will never do much more than take her place by the side of the circular hulks which originated in the same ingenious brain, and furnish another curiosity in the Black Sea. It does not seem that she will enjoy the privilege of carrying the new Czar to the Crimea, for the latest report gives it as the intention of the Imperial Admiralty to build another yacht of steel of the same kind as the old yacht "Livadia," which foundered off the Crimean coast. In any case, the success of the "Livadia" seems more than ever doubtful. The version of the damage done to her bottom, as given at the time by Sir E. J. Reed and others, has not been borne out by the independent Russian authorities who have gone into the matter. On the contrary, the floating wreckage theory is flatly contradicted here. The "Livadia" has, or had, several large cracks, one being as much as 10 feet long and 1 foot wide—a hole which it is impossible to repair without a dock. This being the case, and in view of the fact that the sides or ribs of the fore part of the vessel are damaged or strained, it is impossible, the Russians say, that wreckage alone could have been the cause of the accident. Moreover, it is observed, the screws and their appurtenances would inevitably have been considerably damaged by floating wreckage passing under the ship, and this is not found to have been the case. This matter of the "Livadia," however, forms only a small part of the general accusation which the Russian press has brought against the Imperial naval authorities. Excessive expenditure with the meanest results in naval progress is the theme of the *Golos*. 'The Naval Budget of Russia for the ten years between 1870 and 1880, when compared with that of England for the same period, shows that, although the sum spent by Great Britain on naval construction was only between two and three times more than the amount expended by Russia on the same account and for the same time, England acquired six times the number of new vessels that Russia did, to say nothing of their quality. For the ten years ended with 1880 the Russian Ministry of Marine spent 298,920,910 roubles, of which 72,000,000, or only 26 per cent of the whole sum, was devoted to ship-building proper. For this sum Russia got the "Peter the Great," the two "Popofkas," three frigates, eight clippers, four cruisers from America, four Imperial yachts, including the "Livadia," four schooners, nine gunboats, two torpedo boats fit for sea, and 115 torpedo sloops unfit to leave the coast. In other words, after putting aside the two "Popofkas" and other smaller vessels good for coast defence only, the Russian fleet was augmented for the above amount by only one ironclad, three semi-ironclads, twelve other seagoing vessels, and four yachts for passenger service. A glance at English expenditure on naval construction for the same decade shows that for £19,200,000, or 170,213,000 roubles, we acquired twenty-four ironclads, three frigates, thirty corvettes, fifty-two clippers, fifteen gun-

boats, six transport vessels, and a large number of smaller vessels for coasting service. The Russian Naval Budget is the third in the world, but the facts just mentioned show how little the Russian Government gets in reality for its enormous outlay on naval improvements and novelties.'"

[Sir Edward J. Reed, in replying to the above letter, as far as it concerns the "Livadia," states that the correspondent is in error in supposing that the Russian authorities contradict him when they say that "wreckage alone would not have caused the accident" to the "Livadia," when they include under the word *accident* all the damage and straining at the fore part of the vessel. Much of this damage and straining, Sir Edward affirms, was due, doubtless, to the absence of certain reverse frames and other details, of the necessity for which he spoke quite freely both before the ship left the Clyde and after she arrived at Ferrol. The wreckage theory was resorted to as an explanation—and what to Mr. Pearce and others on board seemed the only explanation—of two holes with which the bow bottom had been pierced in its very strongest part. These holes, he was obliged to admit, bore every appearance of having been caused by wreckage—as if by the iron cross trees or other fittings of a floating wooden mast, for example. With these holes manifest to their eyes, he certainly did not think it necessary to insist publicly upon his own view of the local weakness of the bow, resulting from the absence of reverse frames, &c., especially as these were mere matters of detail which could be readily put right at Sebastopol. Sir Edward Reed continues: "I do not think Admiral Popoff can much complain of the adverse inferences and comments which have resulted from the ship having been made to winter at Ferrol. Although a mere visitor on board, I did all I could to avert what was certain to occasion a general distrust of the ship. But Russian ways are not our ways, and the ship remained, the reputation which her great and original qualities ought to have secured for her being sacrificed to mere matters of detail and convenience. Such a mode of dealing with such a ship is, I confess, enough to justify grave distrust in other respects. At the same time, I must say, in common fairness, that the proposal to sheathe the immersed hull with planking, to be afterwards coppered, is not at all an after thought, but formed part of Admiral Popoff's original intention. This I state from personal knowledge."]

BOOK NOTICES

Publications Received.

The Monthly Weather Review for April. Washington: Government Printing office.

Progress of the Works of Completion of the New Improved bed of the Danube at Vienna. By Sir Gustave Wex. Translated by G. Weitzel, Maj. of Engineers and Bvt. Maj. General. Washington: Government Printing Office.

Professional Papers of the Corps of Royal Engineers. Vols. IV. and V. London: Royal Engineer Institute.

Annual Report upon the Surveys of Northern and Northwestern Lakes, in charge of C. B. Comstock, Maj. of Engineers and Bvt. Brigadier-General. Washington: Government Printing Office.

Evansville Water Works. Report of the Expert (John W. Hill) on the Trials of the Gaskill Compound Pumping Engine. Cincinnati: Robert Clarke & Co.

Report of the Expert on the Test Trials of Automatic Cut-off Steam Engines, at the First Millers' International Exhibition at Cincinnati, June, 1880.

The Telescope: The Principles Involved in the Construction of Refracting and Reflecting Telescopes. By Thomas Nolan, B. S. New York: D. Van Nostrand. Price 50 cents.

This is a reprint from the articles on "The Telescope" in the first three numbers of this magazine for the current year. It forms No. 51 of Van Nostrand's Science Series.

The author claims no originality except for the form in which the subject is presented. To all who are familiar with the elementary principles of geometry and of optics, the construction of the telescope is made exceptionally plain.

The author is particularly happy in his method of explaining the theory of the various eye-pieces, and in elucidating the obstacles encountered in dealing with the Secondary Spectrum in large Refracting telescopes.

The illustrations are for the purposes of demonstration, and are very good.

Graphical Determination of Forces in Engineering Structures. By James B. Chalmers, C. E. London, 1881. For sale by D. Van Nostrand. Price $6.50.

This is something more than a practical application of Graphic Statics to Structures, for it presents quite clearly the theoretical principles of the science.

Its chief value to engineering students, however, lies in the fact that it presents applications to other problems than those relating to framed structures. Retaining walls, tunnels and voussoir arches receive a fair share of attention.

A complete treatise on Projective Geometry, which forms the ninth chapter, will prove interesting to mathematical students, as it presents a summary of the various theorems of modern geometry collected from the works of many authors, and upon which the science of graphic statics is founded.

Induction Coils—How made and how Used—Science Series No. 53.—New York: D. Van Nostrand. Price 50 cents.

This useful little treatise has reached its eighth English edition, and it is this last which is now reprinted for the American market.

The "Induction Coil" is now to be obtained of any dealer in physical apparatus and

at a price which is rapidly extending its use by teachers.

Many experimenters are imperfectly acquainted with the resources of this instrument, and can get but imperfect suggestions from the text books in common use. To supplement such books is the object of this little handbook. It is abundantly illustrated, and the directions for the selection or construction of batteries, and the preparation of experiments with the coil, are of the most specific kind.

PRACTICAL ORGAN-BUILDING. By W. E. Dickson, M. A. London: Crosby Lockwood & Co. For sale by D. Van Nostrand. Price $2.00.

The work is designed as a guide to amateurs, and gives specific directions in the matter of constructing the parts in detail.

The contents present the following topics:

Chapter I. Plant and Materials.
II. The Stopped Diapason.
III. The Sound-Board.
IV. The Sound-Board.
V. The Wind-Chest.
VI. The Bellows: Trunks and Frame.
VII. Plantation of Pipes.
VIII. The Action.
IX. Voicing and Tuning.
X. The Draw Stops.
XI. Pedals.
XII. Two-Manual Organs.

THE PLUMBER AND SANITARY HOUSES—(Second Edition.)—By S STEVENS HELLYER. London: B. T. Batsford. For sale by D. Van Nostrand. Price $4.00.

With the wide demand for an improved method of house drainage there has arisen, quite naturally, a demand for a better knowledge of the conditions to be met and the evils to be avoided.

The work before us is chiefly remarkable for the directness with which the author attacks the problem of house sewage. There are no pages wasted on theories of ventilation or drainage, but with the briefest possible statement of what is to be done, the author proceeds to point out how, through ignorance, people often fail to do it, and appealing to common sense and an elementary knowledge of physics he exhibits to the reader the various correct ways of avoiding the common errors.

The illustrations are numerous and exceptionally well designed to exhibit the various approved sanitary appliances.

THE WOOL CARDERS VADE MECUM— By WILLIAM CALVERT BRAMWELL. Third Edition. Boston: Thayer & Wadham. For sale by D. Van Nostrand. Price $2.50.

A work designed for a class interested in a single industry only. The present edition is prepared with considerable matter not in the previous editions, in response to demands for a more comprehensive work.

It now contains:

Part I. "Animal Fibres," "Vegetable Fibres," "Re-manufactured Fibres."

Part II. "Wool Washing," "Wool Blending," "Wool Oiling."

Part III. "The Carding Engine," "The Carding Process," "Practical Operations."

Part IV. "Appendix," "Tables," &c. "Historical Review."

LATHE WORK—By PAUL N. HASBUCK. London: Crosby Lockwood & Co. For sale by D. Van Nostrand. Price $2.00.

There are many amateur lathe workers, whose labor would yield more satisfactory results if they had at hand a convenient manual like the one here offered. The directions are explicit, and from one who understands the difficulties usually met, and how to overcome them.

CONTENTS:

I. The Art of Turning.
II. The Foot Lathe.
III. Hand Turning.
IV. Screw Cutting by Hand.
V. Boring and Drilling.
VI. Mounting Work for Turning.
VII. Fitting Chucks.
VIII. Various Chucks described.
IX. Slide Rests.
X. Slide-Rest Tools.
XI. Slide-Rest Cutter, Bars.
XII. Overhead Gearing.
XIII. Dividing Apparatus.
XIV. The Drilling Spindle.
XV. Vertical Cutter Frame.
XVI. Screw Cutting by Self-acting Motion.

STEAM BOILERS; THEIR DESIGN, CONSTRUCTION AND MANAGEMENT. By William H. Shock, Engineer-in-Chief, U. S. N., Chief of Bureau of Steam Engineering, U. S. Navy New York: D. Van Nostrand; London Sampson Low, Marston, Searle and Rivington.

Of this extensive work, noticed some time since in this journal, our English contemporary, "Engineering," in giving a summary of the topics treated says:

"The very handsome volume before us has, apart from its intrinsic merit, a special interest from that the fact the position of its author gives it a semi-official character, and entitles it to be regarded as an exponent of the most advanced practice in the United Navy. In fact, although the earlier part of the work treats of theoretical principles applicable to boilers generally, yet those chapters which treat of constructive details relate chiefly to American marine practice. That this fact will in no way detract from the interest of the work to English readers we need scarcely say. All engineers who are acquainted with the working of the Bureau of Steam Engineering of the United States Navy well know that there have been carried out under the auspices of this Bureau numerous series of researches which have added much to our stock of data bearing upon steam engine and boiler construction, and this being so a work which embodies the results of many of these researches has a pecial claim to our attention.

* * * * *

Altogether, Mr. Shock has produced a book which forms a most valuable addition to the engineer's library, embodying as it does an able summary of the best European and American practice, in addition to the results of the author's own practical experience. We

should state, also, that in addition to numerous engravings in the text the work is illustrated by thirty-six well-executed plates of boilers and boiler details (the latter drawn to a large scale), while as a specimen of typography it is admirable."

MISCELLANEOUS.

THE CORROSION OF IRON IN BOILERS.—The oxidation of iron immersed in ordinary water appears to be largely due to two causes, namely, first the absorption of oxygen contained in the water, and second, the absorption of oxygen set free during the decomposition of the water, hydrogen being set free in the latter case. M. Lodin, who has made a number of experiments on the corrosion of iron wires immersed in water and various solutions, and who has described his experiments in the *Comptes Rendus*, has arrived at the conclusion that the first of the above causes of oxidation is generally of chief importance. With both distilled and ordinary water the temperature has a very important influence. Thus at 68 degrees Fahr. the quantities of oxygen absorbed per square foot of iron surface per hour when immersed in distilled and calcareous water, respectively, were 0.258 grains and 0.330 grains, while at 212 degrees the quantities rose to about 2.364 grains and 2.579 grains. The immersion of iron in all the waters tested was accompanied by the evolution of hydrogen, the action being least, however, in distilled water. At a temperature of about 260 degrees Fahr., the decomposition of the water was found to be equivalent to the absorption of 0.01 grain of oxygen per square foot of surface per hour for distilled water; 0.0129 grain for calcareous water; 0.0182 grains for water containing one-fifth part of crystallized chloride of magnesium; 0.05 grain for water saturated with chloride of sodium; and 0.067 grain for sea water.

THE GREAT BRUSH LIGHT.—One of the most powerful electric lights ever yet produced was recently exhibited at the factory of the Anglo-American Electric Light Company in Vine street, York-road, Lambeth. This magnificent artificial sun was the second ordered by the Admiralty for service in torpedo work, and was despatched to Portsmouth on Tuesday morning. The light is generated by a sixteen-light machine, and the lamp is of the ordinary Brush type but of unusual size. Each of the field magnets of the machine contains 800 lbs. of silk-covered copper wire. The current was led off by four copper combs each 5 inches wide, and consisting of 16 stout copper teeth, and was taken to the lamp by a ¾ inch copper rope lightning conductor. A Brotherhood engine of 15 horse power drives the machine, being mounted on the same baseplate, and the absolute steadiness of the light is sufficient proof that this type of engine is admirably adapted for the purpose to which it is being very largely applied. The carbons of the lamp are 1¼ inches in diameter, and, such is the extraordinary energy of the current, they are heated white hot at a distance of 2 inches from the arc. A silvered parabolic reflector 3 feet in diameter was placed behind the arc, and projected the light, which was displayed upon the roof of the factory, in a broad divergent beam of great power. The photometric power of the light is stated by the Anglo-American Electric Light Company to be 47,000 standard candles.

IN a note to the Vienna Academy—*Anz.* December 16th—Prof. Stefan describes experiments on the influence of terrestrial induction in development of an electric current, and the excitement of the telephone by currents from a rotating coil. The coil used was 56 mm. in external diameter, and 11 mm. in width. The earth's influence is best shown by so connecting the apparatus with a galvanometer that the circuit is closed during one-half of the coil's rotation, and broken during the other half; if the completion of the circuit correspond to the positive maximum of the electro-motive force of the earth's magnetism, and the interruption to the negative, the galvanometer is positively deflected. The deflection may be reduced to zero by displacing the contact, and from the displacement and the number of rotations the potential may be inferred in absolute measure. Next, the telephone was so connected with the coil that the full alternately opposite currents went uninterruptedly through the circuit. This gave a simple tone. With 100 rotations per second the horizontal component of the earth's magnetism did not suffice to excite an ordinary telephone, but it excited one having a horseshoe magnet. When the intensity of the field was doubled the ordinary telephone was also excited. The tone corresponds to the number of rotations. When the coil was rotated 220 times in a second the ordinary telephone sounded. The telephone was shown to be less sensitive to currents whose intensity periodically changes than to interrupted currents—an ordinary telephone sounded with 100 rotations or fewer, when the circuit was closed only during a short time of each rotation.

BOUDET'S MICROPHONE. — A convenient form of microphone for telephonic purposes has been contrived by M. Boudet, of Paris. It consists of a mouthpiece for speaking into, closed by an ebonite disc. one millimeter in thickness. This is the vibrating plate, and carries behind it, attached to its center, a copper plug or piston which presses upon a row of six round pellets of retort carbon filled into a glass tube so as to be in contact with each other. The last pellet rests on a second plug of copper which in turn rests against a delicate spiral spring at the end of the tube. By means of a thumbscrew the force of this spiral spring can be regulated so as to produce the pressure of the microphonic contacts requisite to give the best articulation. The current from six Gaiffe, or chloride of zinc and manganese cells, is sent through the pellets, and the vibratory pressure of the diaphragm upon the pellets gives rise to the undulations of current which passed through the telephone are heard as articulate speech. The whole instrument is mounted on a jointed stand which accommodates it to the speaker.